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Appendix D: Reducing Petroleum Dependency in California (Task 4)

CONSULTANT REPORT

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Reducing Petroleum Dependency In California

Task 4 Report

Contractor Report

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In the broader context of the AB 2076 effort to assess petroleum Dependency in California, there were many staff of both agencies and many of our colleagues that contributed to this effort. These staff and management are indicated below. Without the never-ending energy and contributions of these individuals, this report would never have been completed.

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Executive Summary

This report presents overall cost and benefit results for a variety of petroleum reduction options that respond to the direction contained in Assembly Bill 2076 (Chapter 936, Statutes of 2000). The legislation requires the California Energy Commission (Energy Commission) and the California Air Resources Board (ARB) to develop and submit a strategy to the Legislature to reduce petroleum dependence in California. To provide a basis for a strategy and explore specific mechanisms described in the enabling legislation, the Energy Commission and the ARB have projected consumption trends and performed costs and benefits analysis on petroleum reduction options.

The statute also requires the strategy to include recommended goals for reducing the rate of growth in consumption of petroleum fuels, primarily conventional forms of gasoline and diesel fuels. Elements of the strategy shall include increasing transportation energy efficiency and using non-petroleum fuels and advanced transportation technologies including alternative fueled vehicles and hybrid vehicles. The strategy and recommended goal are presented in a summary report entitled "Reducing California's Petroleum Dependence".

What is the Problem?

California's demand for petroleum transportation fuels continues to grow, and is expected to increase by 50 percent in the next 20 years. The California refining capacity has not been able to keep up with the growing demand for transportation fuels. As a result, the demand for imported refined product is increasing. The supply of crude oil from California and Alaska is also declining, making more of California's refining capacity dependent on foreign crude. These trends pose three problems for California:

1. Growing dependence on transportation fuels (crude or refined product) originating in politically unstable regions of the world makes the state's economy more vulnerable to external disruptions and volatility in fuel prices.
2. Increasing use of petroleum fuels results in additional climate change emissions such as carbon dioxide. Global climate change is projected to cause environmental and economic damage to California.
3. In the longer term, beyond 2020, the world supply of petroleum is projected to fall short of demand, significantly increasing the price of petroleum products.

While these factors form the essence of our petroleum dependency concerns, superimposed on top of these long-term trends are economically harmful short-term fuel price spikes. Price spikes result from the combination of high in-state refinery utilization rates, low product inventories, and limited out-of-state sources for fuels meeting California's unique clean air specifications. Since 1996, unplanned refinery outages have often resulted in price spikes because additional supplies must be imported over large distances and on short notice. Measures designed to address this short-term volatility are examined in a separate report.

The continued reliance on petroleum fuels for transportation combined with a projection of increasing consumption rates for these fuels lead to a problematic energy future. Allowing these trends to continue unimpeded today compounds the difficulty of reversing their ill effects and constrains the choices we have to avoid a chaotic energy market in the future.

What are Our Options and Their Costs and Benefits?

The Energy Commission and Air Resources Board have evaluated the relative merit of petroleum reduction options based on estimated costs and benefits. For each option, the annual amount of petroleum fuel displaced compared to the base case (business-as-usual case) was estimated. An economic analysis for each option was performed, estimating consumer expenses or savings, government investment and revenue impacts, environmental benefits or damages, and the impact on external costs of petroleum dependency (ECPD). The economic elements are summed within three categories described as direct non-environmental net benefit (DNNB), direct environmental net benefit (DENB), and ECPD. The categories are then combined to produce an overall measure of economic merit, direct net benefit (DNB).

The petroleum reduction options were grouped into four main categories: Group 1 fuel efficiency options, Group 2 fuel substitution options, Group 3 pricing options, and Group 4 other options. Tables S-1, S-2 and S-3 present the analysis results for selected options from Groups 1, 2 and 3, respectively. As can be seen, the DNB ranges from negative impacts to fairly large positive benefits. Also shown is the relative contribution of various benefits. DNNB contributions are generally positive when the cost of the technology is less than lifetime vehicle fuel savings. Environmental benefits are achieved for most options as a result of less gasoline being distributed and used in vehicles. Similarly, the impact on ECPD is positive for all options as a result of reduced petroleum consumption.

It is important to note that the magnitude of values in Tables S-1 and S-3 cannot be directly compared to those in S-2 because of differences in analytic methodology. Specifically, the fuel economy options assumed 100 percent new vehicle market penetration and the pricing options affected the entire gasoline vehicle fleet while most of the substitution options assumed a 10 percent new vehicle market penetration. One exception is the diesel fuel option for light-duty vehicles, which was evaluated as a fuel substitution option with 10 percent market penetration. This option was subsequently compared to the fuel economy options since this option primarily increases vehicle fuel economy instead of displacing petroleum.

Clearly, the most effective options are those that provide large petroleum reductions with low technology costs. In general, the Group 1 fuel efficiency options are more effective than the Group 2 fuel substitution options in this analysis. In particular, the ACEEE advanced option and the ARB mild hybrid option provide the most petroleum displacement with the highest DNB. In these cases there is considerable value to the consumer (measured by DNNB) along with environmental benefits and reduced costs associated with petroleum dependency. The ACEEE full hybrid option is the only vehicle fuel economy option resulting in negative DNB. In this option, the technology costs exceed the combined life cycle fuel savings and the environmental and petroleum dependency benefits.

Table S-1. Selected Fuel Efficiency Option Midpoint Results

Selected Fuel Efficiency Options	Displacement in 2030, Billion gal/yr gasoline equivalent	Cumulative Benefit, 2002-2030, Billion $2001			
		Direct Non-Environmental Net Benefits	Direct Environment Net Benefits	External Cost of Petroleum Dependency	Direct Net Benefits
Improved Light-Duty Fuel Economy					
ACEEE Moderate, 30 mpg	6.28	16.92	5.59	3.35	25.86
ACEEE Advanced, 34.4 mpg	8.04	19.54	7.16	4.30	31.00
ACEEE Mild Hybrid, 40 mpg	9.71	-7.28	8.65	5.19	6.56
ACEEE Full Hybrid, 45 mpg	10.86	-27.15	9.68	5.80	-11.67
ARB Mild Hybrid, 40 mpg	9.71	19.42	8.65	5.19	33.26
ARB Full Hybrid, 45 mpg	10.86	-2.23	9.68	5.80	13.25
Fuel Efficient Replacement Tires and Inflation	0.41	3.04	0.78	0.47	4.28
Efficient Government Light-Duty Fleets	0.02	0.17	0.02	0.01	0.21
Improved Vehicle Maintenance	0.05	-0.14	0.10	0.06	0.03
Efficient Diesel Medium-Duty Vehicles	0.07	0.18	0.06	0.03	0.26
Efficient Diesel Heavy-Duty Vehicles	0.43	1.73	0.33	0.18	2.24
Diesel for Light-Duty Vehicles (30.5 mpg)	0.40*	0.68	-0.07	0.29	0.90

*Net petroleum displaced.

Table S-2. Selected Fuel Substitution Option Midpoint Results

Fuel Substitution Options	Displacement in 2030, Billion gal/yr gasoline equivalent	Cumulative Benefit, 2002-2030, Billion $2001			
		Direct Non-Environmental Net Benefits	Direct Environment Net Benefits	External Cost of Petroleum Dependency	Direct Net Benefits
Light-Duty Vehicle Options					
Direct Hydrogen Fuel Cell[1]	1.96	-2.80	0.83	0.55	-1.43
Methanol Fuel Cell[2]	1.96	-1.84	0.68	0.55	-0.61
Gasoline Fuel Cell[2]	0.65	-1.96	0.31	0.18	-1.47
Electric Battery Full Size Vehicle	2.33	-5.80	1.29	0.94	-3.57
Grid Connected Hybrid (20-mile ZEV)	1.65	0.58	1.14	0.67	2.39
Compressed Natural Gas (CNG)	2.33	-6.59	0.29	0.94	-5.36
Liquefied Petroleum Gas (LPG)	2.33	-1.96	0.24	0.94	-0.78
Low Cost FFV[3,4] fuel	1.28	-0.84	0.31	0.50	-0.03
E85 (85% ethanol blend) in FFVs[3]	1.72	-3.47	0.28	0.70	-2.48
E10 (10% ethanol blend)[5]	0.96	-4.38	1.25	0.98	-2.15
Heavy-Duty Vehicle Options					
CNG	0.13	-0.41	0.01	0.08	-0.32
Liquefied Natural Gas	0.13	-0.01	0.01	0.08	0.07
Fischer-Tropsch Diesel[5,6] (33% blend)	1.83	0.93	-0.12	1.03	1.84
Biodiesel[5] (2%)	0.11	-0.43	0.09	0.10	-0.25
Biodiesel[5] (20%)	1.06	-2.48	0.62	0.69	-1.16

Notes:

1. The direct hydrogen fuel cell assumes natural gas as feedstock
2. The gasoline and methanol fuel cells assume on-board reforming.
3. FFV = Flexible Fuel Vehicle
4. The Low Cost FFV fuel is a 40 percent ethanol 35 percent gasoline blend with other components not currently present in California gasoline.
5. The E10, FTD and biodiesel options assume all fuel sold as a blend.
6. FTD assumes remote natural gas as the feedstock.

Table S-3. Selected Pricing Option Results

Selected Fuel Efficiency Options	Displacement in 2030, Billion gal/yr gasoline equivalent	Cumulative Benefit, 2002-2030, Billion $2001			
		Direct Non-Environmental Net Benefits	Direct Environment Net Benefits	External Cost of Petroleum Dependency	Direct Net Benefits
Gasoline Tax ($0.50 per gallon)	1.05	-5.20	2.83	1.33	-1.00
Pay-at-the-Pump Insurance	0.88	-1.20	2.32	1.09	2.18
Pay-as-you-Drive Insurance	0.59	-0.40	1.85	0.81	2.23
Tax on Vehicle Miles	0.63	-3.40	1.96	0.86	-0.56
California Feebate	1.43	6.10	1.63	1.01	8.72
National Feebate	4.26	26.90	4.40	2.83	34.13
Registration Fee Transfer	0.17	-0.50	0.46	0.22	0.22
Efficient Vehicle Incentives	0.13	-1.10	0.19	0.11	-0.84

The medium- and heavy-duty vehicle fuel economy options displace less petroleum than the light-duty fuel economy options but yielded positive DNB. This is because there are more light-duty vehicles, and heavy-duty diesel engines are already more efficient than their gasoline counterparts.

The other effective fuel efficiency options include the fuel-efficient replacement tires and proper tire inflation program, improved vehicle maintenance, and the use of efficient vehicles by government fleets. While these options could be implemented relatively quickly, the magnitude of displacements is much less than the other fuel efficiency options.

Of the Group 2 fuel substitution options, grid-connected hybrid vehicles with a 20-mile ZEV range, Fischer-Tropsch diesel, and Liquefied Natural Gas heavy-duty vehicle options were found to provide positive DNB. In contrast, all the other fuel substitution options result in negative DNB. This is because the cost of alternative fuels is higher than the price of petroleum fuels assumed in this analysis (gasoline at $1.64 and diesel at $1.65 per gallon). The environmental and petroleum dependency benefits are insufficient to offset the higher fuel costs. As a result, some form of subsidy may be needed to allow these alternative fuels to thrive in the marketplace. However, if the price of petroleum fuels were to increase to the $2.00 to $2.50 range on a sustainable basis, most of the alternative fuel options would provide positive DNB. For this reason, continued investment in technology and efforts to remove market barriers and integrate these technologies and fuels into the existing transportation infrastructure makes sense.

Results for the Group 3 Pricing Options ranged from very positive, as in results for the State or National Feebate Options, to somewhat negative, as in the result for the option of increasing the gasoline excise tax by $0.50 per gallon.

What are the Key Findings of This Report?

1. Improving vehicle fuel economy, using available and emerging technologies, provides large reductions in fuel use, and for most options evaluated, saves the consumer money while also providing environmental and petroleum dependency benefits to society. For example, a fuel economy standard for cars and light trucks of 35 to 40 miles per gallon could reduce petroleum fuel use by nearly 10 billion gallons per year when fully implemented (2030) while saving society about 1 billion dollars per year. Technologies that can substantially improve fuel economy include more efficient engines and transmissions and gasoline hybrid electric vehicles.

2. Smaller but significant reductions in fuel use can be realized quickly through state government actions. One half billion gallons per year of fuel can be saved with an efficient tire program, improved maintenance of vehicles, and government fleets which use the most efficient vehicles available. The net benefit to society of these programs is about $150 million per year.

3. Some alternative fuel options are cost-effective at the fuel price range used in this analysis. Grid-connected electric hybrids with a 20-mile all-electric range, Fischer-Tropsch diesel fuel and liquid natural gas used in heavy-duty trucks are all cost-effective. These options would save about 3.5 billion gallons of gasoline and diesel consumption per year.

4. At current projected gasoline and diesel fuel prices, the widespread use of other alternative fuels would require subsidies due to their higher cost. However, the trend towards higher consumption and the longer-term increased reliance on more costly imported fuels could dramatically increase gasoline and diesel prices relative to the alternatives. At $2.00 to $2.50 per gallon of gasoline and diesel, most of the alternative fuels evaluated in this study would become cost competitive.

1. Problem Statement

California's demand for petroleum transportation fuels continues to grow, and is expected to increase by 50 percent in the next 20 years. The California refining capacity has not been able to keep up with the growing demand for transportation fuels. As a result, the demand for imported refined product is increasing. The supply of crude oil from California and Alaska is also declining, making more of California's refining capacity dependent on foreign crude. These trends pose three problems for California:

1. Growing dependence on transportation fuels (crude or refined product) originating in politically unstable regions of the world makes the state's economy more vulnerable to external disruptions and volatility in fuel prices.

2. Increasing use of petroleum fuels results in additional climate change emissions such as carbon dioxide. Global climate change is projected to cause economic damage to California.

3. In the longer term, beyond 2020, the world supply of petroleum is projected to fall short of demand, significantly increasing the price of petroleum products.

While these factors form the essence of our petroleum dependency concerns, superimposed on top of these long-term trends are economically harmful short-term fuel price spikes. Price spikes result from the combination of high in-state refinery utilization rates, low product inventories, and limited out-of-state sources for fuels meeting California's unique clean air specifications. Since 1996, unplanned refinery outages have often resulted in price spikes because additional supplies must be imported over large distances and on short notice. Measures designed to address this short-term volatility are examined in a separate report.

The continued reliance on petroleum fuels for transportation combined with a projection of increasing consumption rates for these fuels lead to a problematic energy future. Allowing these trends to continue unimpeded today compounds the difficulty of reversing their ill effects and constrains the choices we have to avoid a chaotic energy market in the future.

Assembly Bill 2076 (Chapter 936, Statutes of 2000) requires the Energy Commission and the ARB to develop and submit a strategy to the Legislature to reduce petroleum dependence in California. The statute requires the strategy to include recommended goals for reducing the rate of growth in consumption of gasoline and diesel fuels. Options to be considered include increasing transportation energy efficiency and using non-petroleum fuels and advanced transportation technologies including alternative fueled vehicles and hybrid vehicles.

The statute also requires that the strategy include a base case forecast of on-road gasoline and diesel consumption in years 2010 and 2020, based on current best estimates of economic and population growth, petroleum based fuel supply and availability, vehicle efficiency, utilization of alternative fuels, and advanced transportation technologies. The timeframe of the study was also extended to 2050 to allow consideration of: increased dependence of the world oil market on Middle East petroleum sources, the potential for world oil production to peak in coming decades, and the long-term environmental and economic implications of addressing global climate change.

Since 1996, California demand for transportation fuel has hovered closely to California refinery production capacity. As a result of high refinery utilization rates and limited sources of fuel meeting state specifications available outside of California, the state has experienced increasing fuel price volatility. Unplanned refinery outages have an immediate impact on wholesale and retail prices of transportation fuels, especially when refined product inventories are low and make-up supplies must be imported over large distances and on short notice. These constraints subject the state's transportation energy market to economically harmful price spikes. The market impacts of supply disruptions that have occurred in recent years seem to be more severe. Concerns about the economic impacts to California from more frequent and severe periods of gasoline price volatility in 1999 led to the passage of Assembly Bill 2076.

For the foreseeable future, California faces continued risk of fuel supply shortages and price spikes. Currently, the state must import refined products during high use periods to meet consumer demand. The replacement of MTBE with ethanol in our gasoline in 2003 will reduce the state's production volume of reformulated gasoline, adding more pressure to increase imports to makeup for the shortfall in in-state refining capacity. Because no new refineries are currently expected in California, the state must depend on out of state and foreign refiners to augment our supply of transportation fuels. These potential sources are further limited by California's unique clean fuel requirements for gasoline and diesel.

Transportation energy demand continues to grow while California production capacity remains relatively constant. The lack of fuel economy improvements in new gasoline vehicles is a major factor for the relatively high level of projected future growth in transportation energy demand. Constant average fuel economy levels projected for new cars and trucks in the future, combined with higher market penetration for light trucks, result in forecasts of nearly constant fleet average fuel economy for California. The projected rate of demand growth is equivalent to building one world class refinery (120,000 barrels per day) every five years.

In the longer term, experts conclude that world oil supplies will gradually decline, with domestic and Alaskan supplies decreasing long before those in the Middle East. In addition to higher oil prices, this will result in even greater reliance on foreign sources of petroleum, an energy security risk not only for California but also for the rest of the nation.

A two-pronged strategy, enhancing available supplies of petroleum products while relieving pressure on the already tight market, is a primary focus of ongoing efforts at the Energy Commission. Combining actions to dampen price spikes in the short term with measures to reduce the rate of petroleum product demand in the long term can be beneficial to the state's economy and environment. Furthermore, some of these actions would allow for a smooth transition away from total petroleum dependence in the transportation sector. A parallel effort is underway at the Energy Commission to identify supply enhancement measures.

This section of the report details the transportation energy problem facing California. First, background information is provided on the current fuel supply and consumption rate in

California. Information on environmental issues is also provided since petroleum use directly affects both ambient air quality and climate. Finally, the current, mid-term and long-term fuel supply, demand, and price relationships are discussed.

1.1 Background Information

To provide greater understanding of the problem facing California, background information about California's transportation energy supply and usage is provided in this section. This information describes California refining capacity, transportation fuel supply, imports and exports, fuel use by sector, sources of crude oil, and environmental issues linked to petroleum use.

1.1.1 California Refinery Capacity and Output

Historical trends in key parameters for the in-state production of petroleum fuels show California becoming more dependent on the import of refined products. In Figure 1-1 California's refinery capacity is shown to decline. Beginning in 1989, several refineries were shutdown, resulting in a nearly 20 percent loss of refining capacity. The plot also illustrates that California refineries have been operating at an average utilization rate of 97 percent since 1989. This rate is an increase from 92 percent during the period 1982 to 1988. While capacity dropped and utilization rates peaked, demand has increased over the same period. Satisfying the increased demand requires the import of refined products. California refineries also supply a portion of Nevada and Arizona fuel demand.

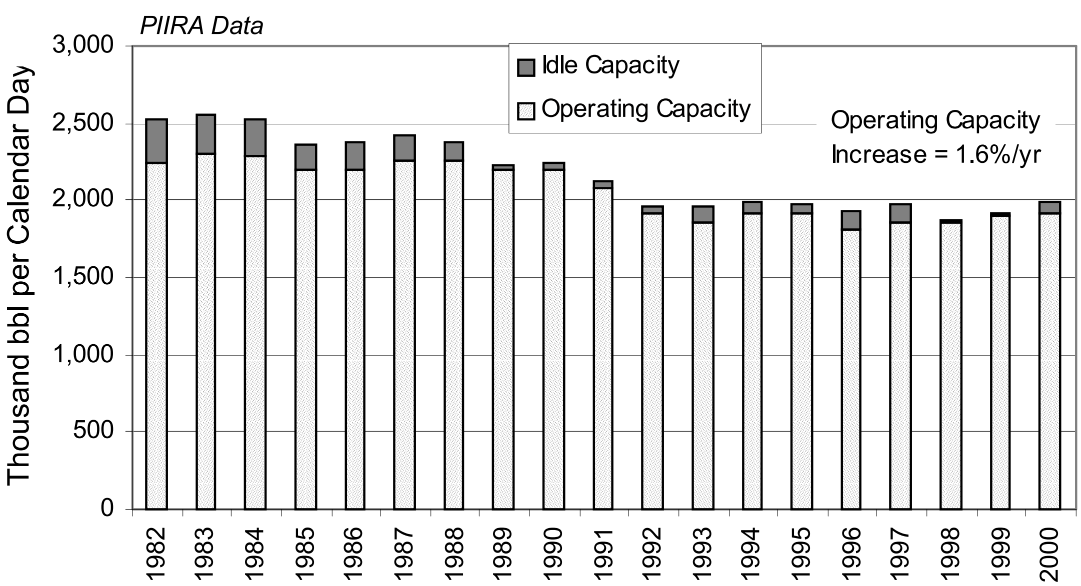


Figure 1-1. California Refinery Idle and Operating Capacities[1]

[1] California Energy Commission, Fuels Office, Jeff Poteet; data compiled from Petroleum Industry Information Reporting Act (PIIRA) submittals, March 2002.

It is interesting to note that declared operating capacity has increased by 1.6 percent per year since 1996. This is attributed to debottlenecking efforts at existing refineries. It is not known with certainty if this trend will or can be maintained.

Figure 1-2 shows that since hitting a peak in 1989, crude oil inputs to California refineries have declined by nearly 10 percent. At the same time, gasoline and distillate production has increased by approximately 3 percent. The increase may be attributed to a combination of higher product conversion rates and increased use of imported blendstocks and oxygenates at refineries.

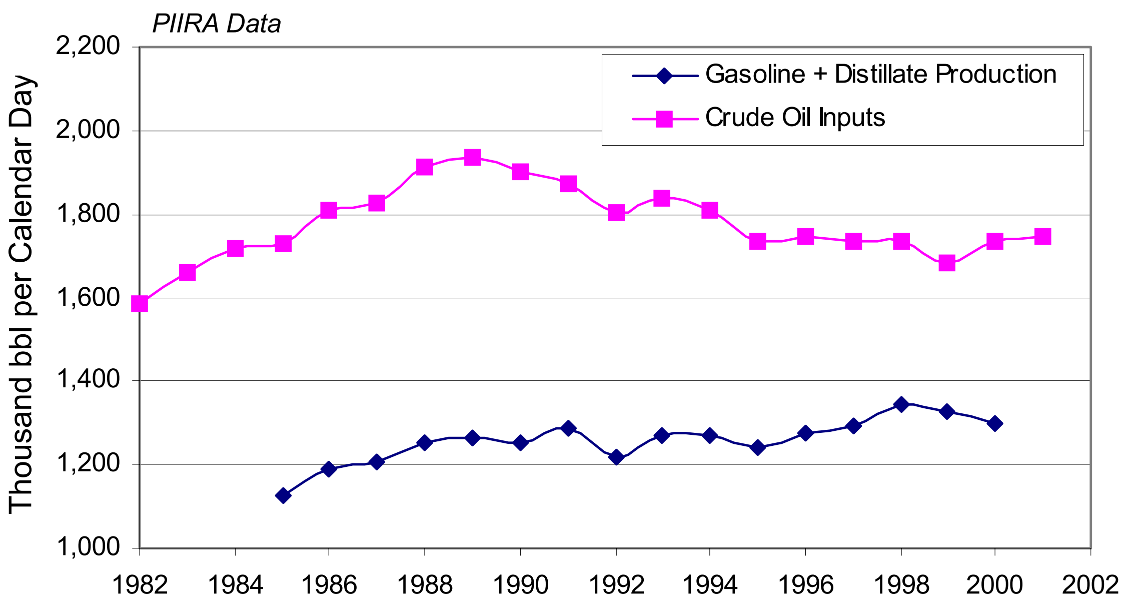


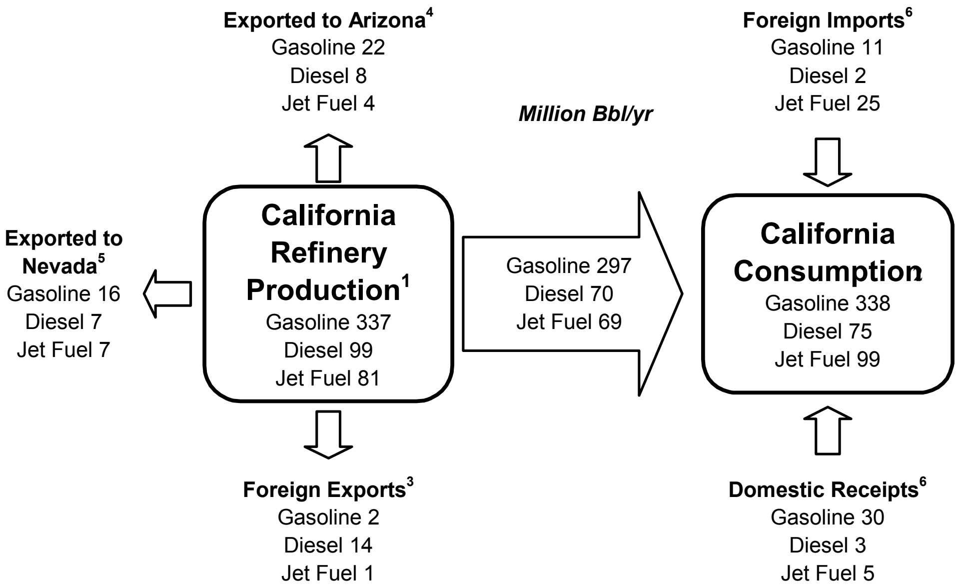
Figure 1-2. California Refinery Crude Input and Production[2]

1.1.2 Fate of Refined Petroleum Products in California

California's production and use of petroleum fuels involves both imports and exports of three primary refined products: gasoline, distillate, and jet fuel. As illustrated in Figure 1-3 in 1999, California refineries produced nearly the same amount of these fuels as consumed by the transportation sector (517 vs. 512 million barrels per year, respectively). California refineries produced almost exactly the amount of gasoline consumed in California. However, approximately 40 million barrels were sent to Arizona, Nevada, and other countries while 41 million barrels were received from other states and countries.

California is a net exporter of distillate. California exported 29 million barrels of distillate, nearly evenly split between foreign and domestic destinations. Most of the distillate exported has higher sulfur content than can be consumed in California.

[2] Ibid.



All data from 1999 EIA Petroleum Supply Annual, unless otherwise noted.
1. 1999 Energy Commission “Weekly Fuels Watch Report”
2. DOE’s EIA Website, “State Information”
3. Foreign exports from PADD V *(CA ref output/PADD V refinery output)
4. Assume CA supplies 40% of AZ consumed (EIA State Information)
5. Assume CA supplies 75% of NV consumed (EIA State Information)
6. Total imports split between foreign and domestic according to PADD V split.

Figure 1-3. Flows of Refined Petroleum Products in California for 1999

California is a net importer of jet fuel. Of the 81 million barrels produced in California, only 69 million barrels were consumed in California, with most of the balance shipped to Nevada and Arizona. California imported 30 million barrels of jet fuel, mostly from foreign countries.

As shown in Figure 1-4, the largest fraction of the state’s transportation fuel consumption is tied to on-road mobile sources, 73 percent. Thus, from a petroleum dependency perspective, this sector became the area of focus in this study. Aviation use is the second largest sector, accounting for 18 percent of the fuel consumed. Off-road and stationary devices consumed only 9 percent of the gasoline, diesel, and jet fuel.

1.1.3 Crude Oil Supplies

Since 1990, the United States has increased imports of petroleum by 45 percent. Imports from OPEC countries have risen by 26 percent while imports from Canada and Mexico have increased by 90 percent. Based upon the amounts and origins of crude oil shown in Figure 1-5, over 60 percent of the crude oil processed in the United States were imported. Imports from the Middle East and North America each represent 18 percent of the crude oil processed in this country.

The trend shown in Figure 1-6 for California refineries also points to growth in crude oil from the Middle East. Crude oil from California and Alaska represented 78 percent of all crude oil refined in California in 1999. By 2001, only 70 percent of the crude oil processed in California was from

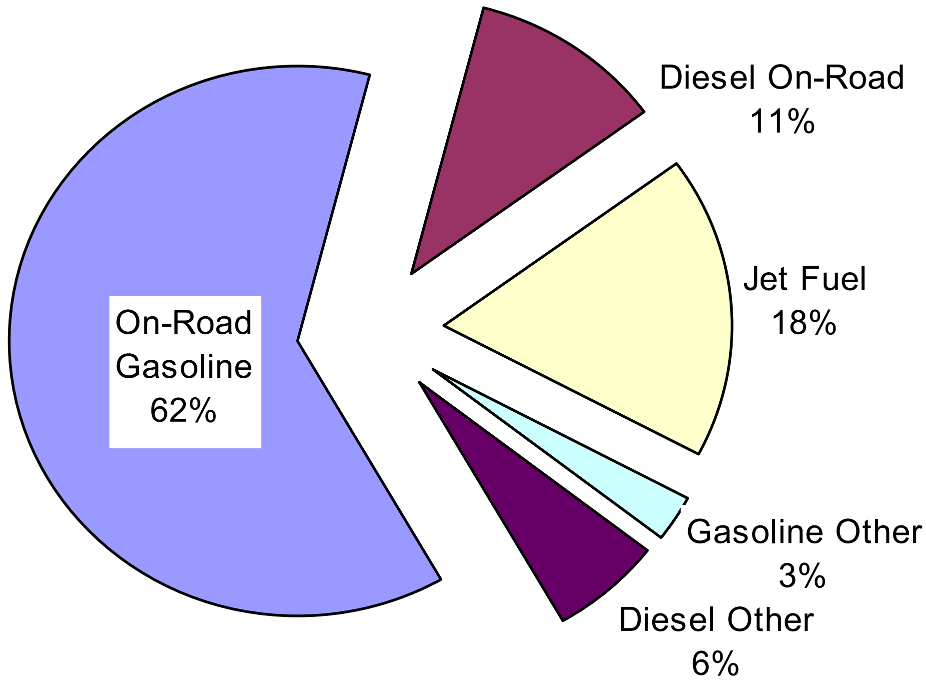


Figure 1-4. Gasoline, Diesel and Jet Fuel Consumption by Sector in California (EIA 2001)

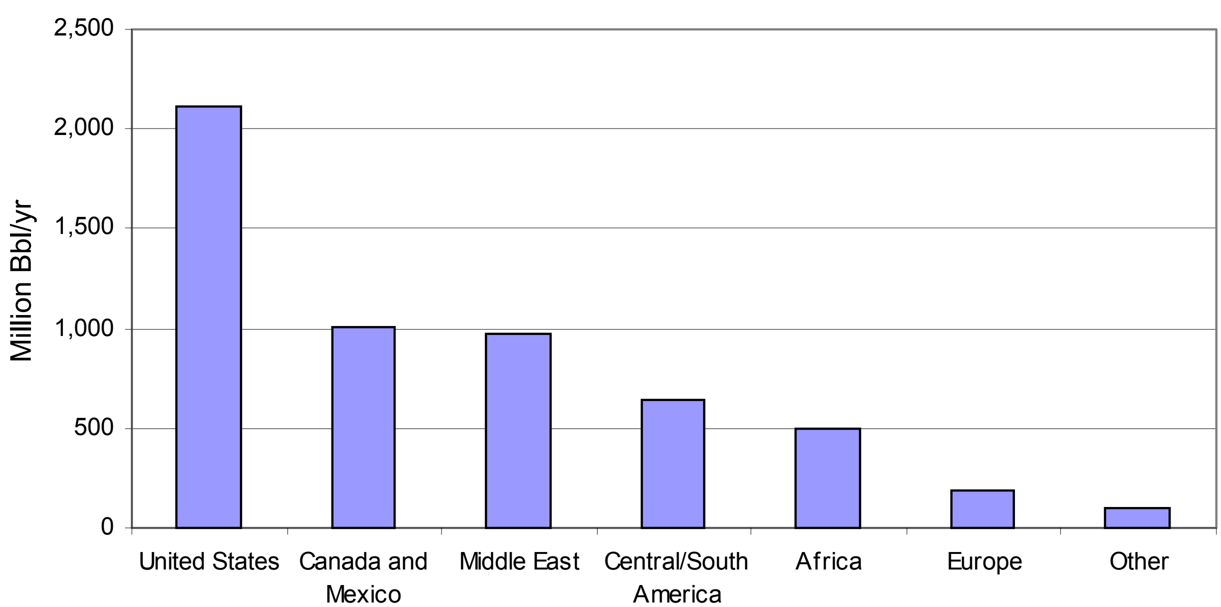


Figure 1-5. Sources of Crude Oil Processed in U.S. Refineries (EIA 2001)

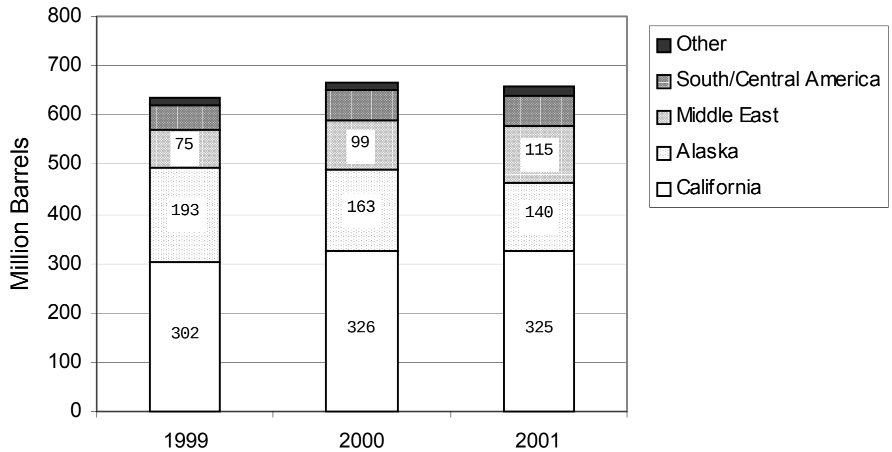


Figure 1-6. Sources of California Crude Oil (PIIRA, Energy Commission/PIERS Data)

California and Alaska. From 1999 to 2001, the amount of crude oil imported from the Middle East grew from 11 percent of all crude oil processed in California to 17 percent.

United States oil fields are past their production peaks, including those relied upon by California. Figure 1-7 shows Alaska and California proven reserves as well as production. Alaska oil production is falling at a rapid rate. If this rate continues, Alaska production will drop from nearly 500 million barrels per year to 100 million barrels by 2010 and to negligible amounts by 2020. In contrast, the Alaska Department of Revenue forecasts 390 million barrels per year in 2010, or essentially the same as current levels. This Alaskan forecast includes production from anticipated new oil fields.

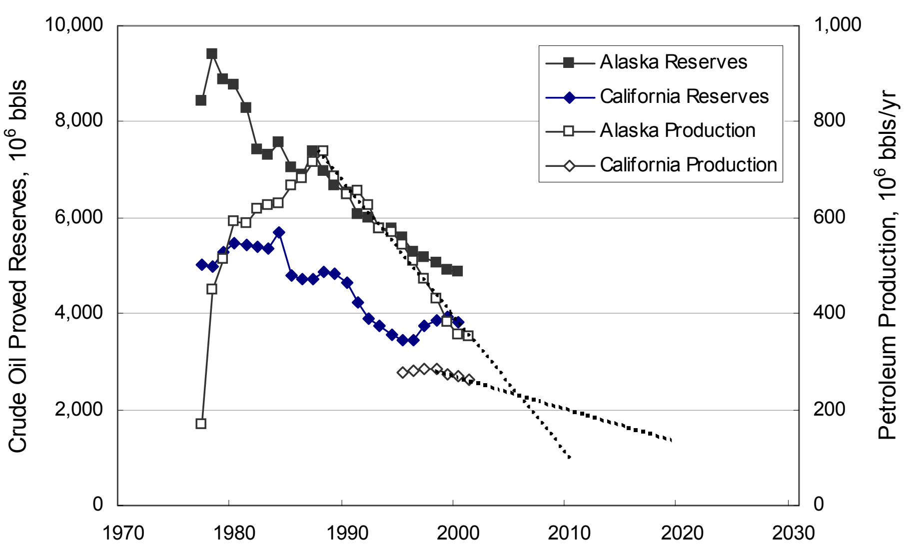


Figure 1-7. California and Alaska Production and Proved Reserves Over Time in California and Alaska (EIA)

Although California oil reserves and production levels are declining more slowly than those in Alaska, it is clear that California will be importing a significant amount of its oil from foreign sources by 2020. The trend line in Figure 1-7 indicates that only 150 million barrels per year will be produced in California in 2020 while the 1999 Energy Commission fuels report[3] projects between 170 and 270 million barrels per year. In 2001, California consumed over 300 million barrels per year of California crude, representing half of the crude oil input to California refineries.

1.1.4 Forecast Supply and Demand

Refining capacity in California is forecast to remain relatively static. No new capacity is currently planned in California or the rest of the United States. However, California refineries have been able to increase production of gasoline and distillate from existing refineries at a rate of approximately one percent per year through a combination of increased product yields, increased product blending, and debottlenecking. For this study, it has been assumed that refinery output will continue to increase at a rate of 0.5 percent per year until 2020 at which point no more increases will be possible.

This year, California refineries will experience a decline in reformulated gasoline volumes due to the replacement of MTBE with ethanol. At present, gasoline contains 11.7 percent MTBE on a volume basis. The new gasoline will contain 5.7 percent ethanol on a volume basis. Furthermore, at certain times of the year a fraction of the pentanes in the refinery stream will have to be removed from the gasoline due to increased evaporative emissions caused by the ethanol. While these effects will reduce the volume of finished gasoline, they are partially offset by increases in alkylates production and other process capacities. The net effect will be a decrease in volume of 3 to 5 percent compared to the current volume of reformulated gasoline. Thus, refineries will have to supply 3 to 5 percent more gasoline to meet projected demand.

Analyses performed by the Energy Commission predict on-road demand for gasoline and diesel fuels to grow by 1.6 percent per year and 2.4 percent per year, respectively until 2020[4] (Ref. Task 2 Report, Volume 2). The slope of the trend line at 2020 was then held constant to portray a potential trend to 2050.

Figure 1-8 provides the forecast demand for on-road gasoline and diesel fuels, the predicted in-state refinery output, and estimated on-road supply.[5] If no measures are taken to mitigate California's demand for on-road fuel, the state will need to import 5 billion gallons of gasoline and diesel fuels (20 percent of the on-road fuel currently consumed) and 20 billion gallons (50 percent of current on-road fuel consumption) in 2020 and 2050, respectively.

[3] California Energy Commission, *1999 Fuels Report*, P300-99-001, July 1999.

[4] *Appendix B: Base Case Forecast of California Transportation Energy Demand*, December 2001.

[5] On-road consumption in 2001 was 88.4 percent of total California gasoline and diesel output. On-road supply shown is this percentage of total output less net exports.

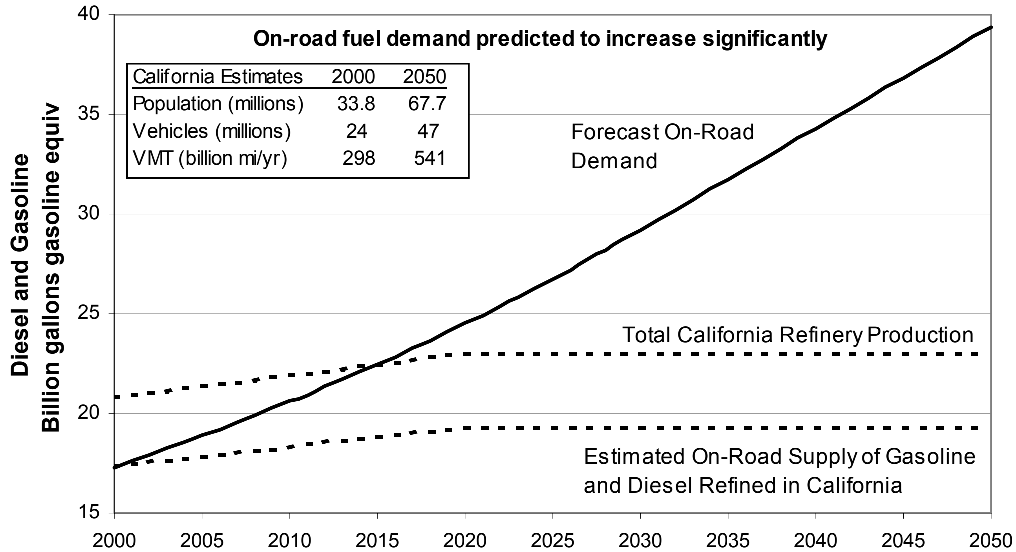


Figure 1-8. Forecast Demand for On-road Gasoline and Diesel Compared to Forecast California Refinery Output

1.1.5 Environmental Issues

Petroleum dependence affects our air quality and contributes to global climate change. The combustion of fossil fuels, including petroleum, produces a number of air pollutants. The main criteria air pollutants due to fossil fuel combustion are carbon monoxide (CO), particulate matter (PM), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and volatile organic compounds (VOC). NO_x and VOC combine in the atmosphere to produce ozone, the compound responsible for "smog." NO_x and SO_2 are also responsible for secondary particulate formation. Fossil fuel combustion also yields carbon dioxide (CO_2), a main contributor to global warming.

Ambient Air Quality Standards

The federal government has established health based National Ambient Air Quality Standards (NAAQS) for each of the criteria pollutants and ozone. California has also established health-based standards for criteria pollutants, which are more protective than the federal standards. Each air basin in California has ambient monitoring stations where the concentrations of each criteria pollutant and ozone are measured continuously and averaged over appropriate time periods to determine compliance with the NAAQS.

As shown in Figure 1-9, most populated regions of California do not attain the standard for ozone and many do not attain the PM_{10} standard. In Figure 1-10, mobile sources (both on-road and other mobile sources) emit 66 percent of the ozone precursor emissions (NO_x and VOC/ROG). Thus, many regions place emphasis on reducing emissions from mobile sources to reach attainment. The various air districts in California are required to develop and implement plans that allow for attainment of each of the ambient air quality standards. Failure to implement

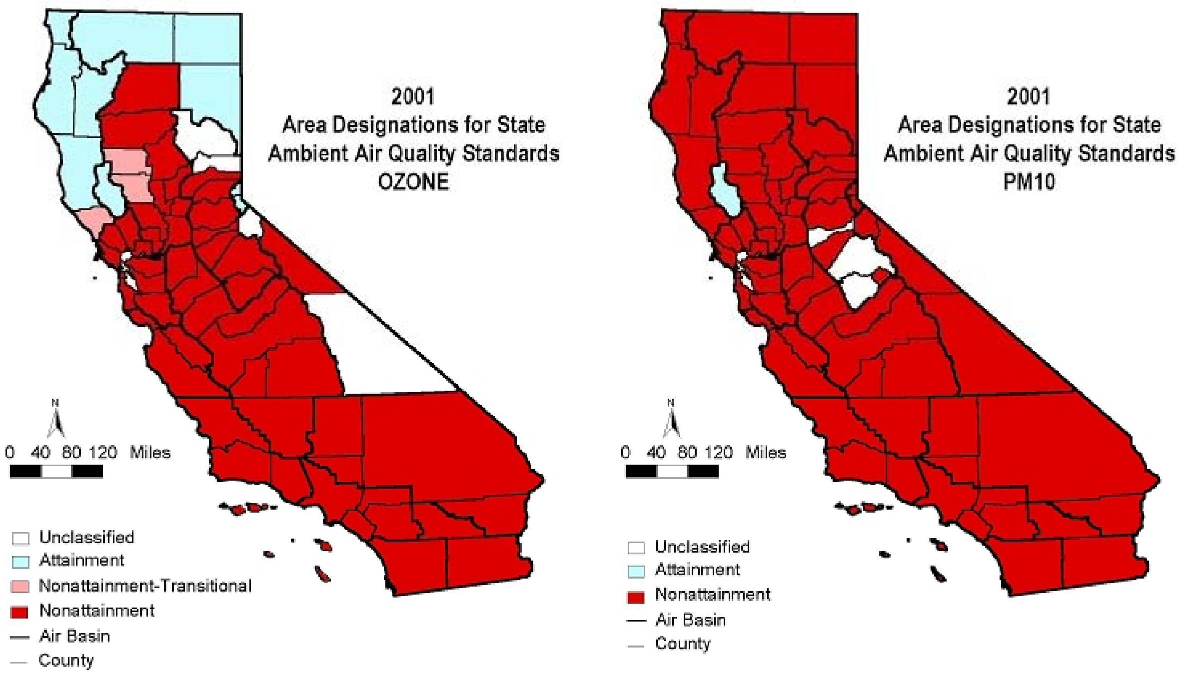


Figure 1-9. California Ozone and PM_{10} State Nonattainment Areas as of 2001

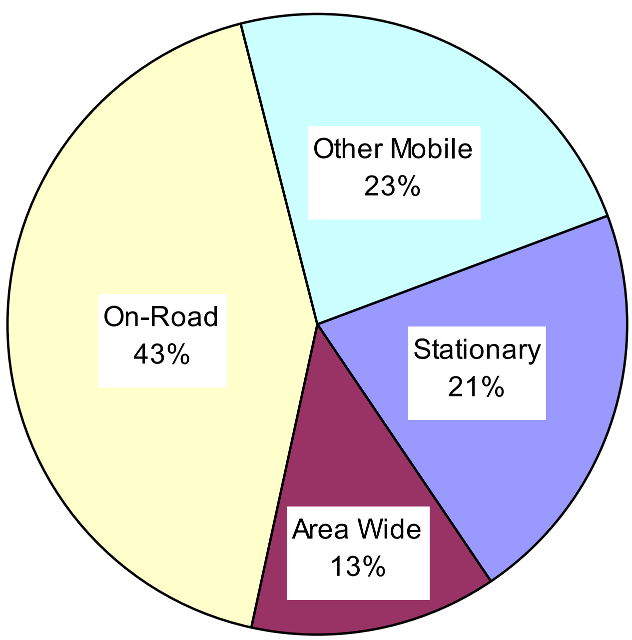


Figure 1-10. Statewide Emission Inventory of Ozone Precursors (NO_x+ROG) by Major Source Category (ARB 2002 Emission Inventory)

the plans can result in loss of federal transportation funds. In addition, failure to comply with these standards results in higher health care costs due to increased incidences of illnesses and premature deaths.

It is important to note that increasing the efficiency of gasoline and diesel vehicles does not reduce their primary impact to ambient air quality since light-duty vehicle emission standards are on a gram per mile basis. Generally, car manufacturers will employ sufficient pollution control equipment on any given vehicle to just meet the emission standard and not to perform better than the standard. However, increasing vehicle efficiency has a second order beneficial impact on ambient air quality in that upstream emission events are mitigated. For example, reduced petroleum consumption results in lower emissions at refineries, fewer trucks, trains, and ships transporting fuel, and lower evaporative emissions.

Substituting petroleum fuels with alternative fuels can have a beneficial impact on tailpipe emissions. Battery electric and fuel cell vehicles have no tailpipe emissions, but may have upstream emissions from the production and transport of electricity or hydrogen.

Toxic Air Contaminants

In 1998, California identified diesel particulate matter (diesel PM) as a toxic air contaminant based on its potential to cause cancer and other adverse health effects. Overall, emissions from diesel engines (on- and off-road, stationary, and portable diesel engines) are responsible for the majority of the potential airborne cancer risk in California.

In 2000, on-road diesel engines contributed about 29 percent of statewide diesel PM emission from mobile sources. Medium heavy-duty trucks and heavy heavy-duty trucks generate the majority of these emissions. Much smaller fractions originate from passenger cars and medium-duty vehicles

Global Warming

Most scientists agree that manmade greenhouse gas (GHG) emissions contribute to global warming, but the degree of contribution is still subject to debate and scientific inquiry. The primary GHGs include CO_2, methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). These pollutants pose a danger to public health and the environment on a broad scale. Human health in California is likely to be impacted through changes in air quality, the number of weather related deaths, and a possible increase in infectious diseases.

Water systems are critically important to human welfare, the environment, and the economy in our state. In California, each winter, at the high elevations of the Sierra Nevada, snow accumulates in a deep pack, preserving much of California's water supply in cold storage. Throughout the 20th century, annual April to July spring runoff in the Sierra Nevada has been decreasing. This decreased runoff was especially evident after mid century, since then the water runoff has declined by about ten percent. Agriculture is especially vulnerable to regional climate changes, such as altered temperatures and rainfall patterns, as well as new pest problems that could result from climate change. All forest ecosystems in California, whether natural or managed will likely be affected climate change. Temperature changes, shifting precipitation patterns, and susceptibility to pests and diseases increase fire hazards.

The increasing population of California's coastal areas means that climate change impacts, such as sea level rise (as shown in Figure 1-11) and increased storm surges would impact a large number of people. Climate change may also lead to more frequent and more intense extreme events, such as floods, droughts, and wildfires.

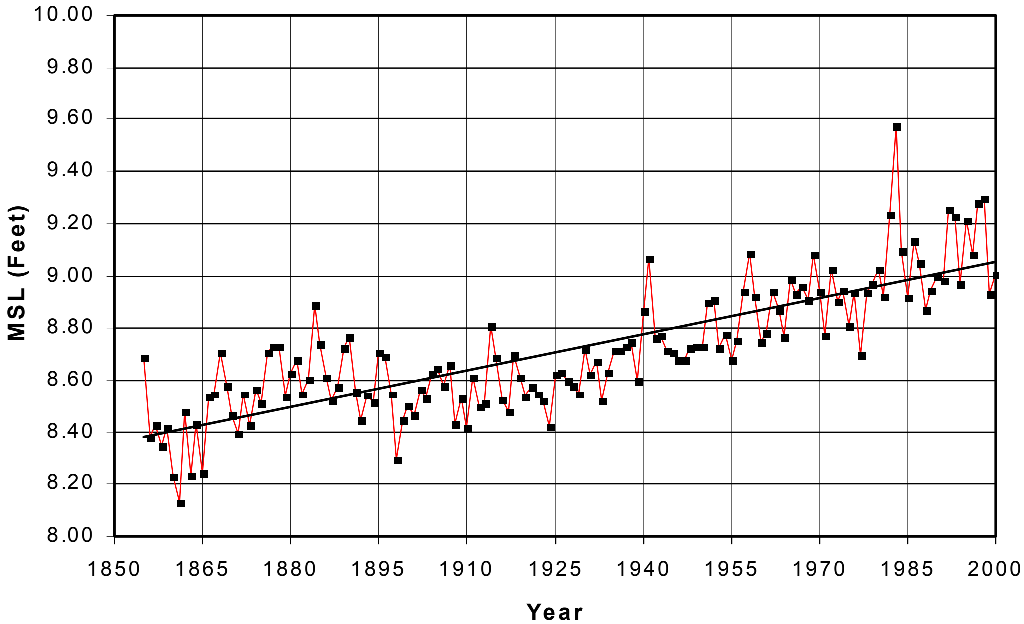


Figure 1-11. San Francisco Yearly Mean Sea Level (California EPA, Environmental Protection Indicators for California, 2001)

Changes in weather patterns can influence the frequency of meteorological conditions conducive to the development of high pollutant concentrations. Higher temperatures cause an increase in emissions: more fuel evaporates, engines work harder, and the demands on power plants increase. There is a positive correlation between air temperature and ozone as shown on Figure 1-12. High temperatures, strong sunlight, and a stable air mass create the ideal conditions for ozone formation. As the temperature rises and air quality diminishes, heat related health problems also increase.

Extreme weather conditions are expected to increase over the coming years. An overall warming trend has been recorded since the late 19th century, with the most rapid warming occurring over the past two decades. The 10 warmest years on record all occurred within the last 15 years.

When the relative warming affect and amounts of GHGs are compared (Figure 1-13) to the combustion sources of CO_2 (Figure 1-14), it becomes clear that the potential control of GHGs must focus on the transportation sector. The transportation sector is the state's primary source of

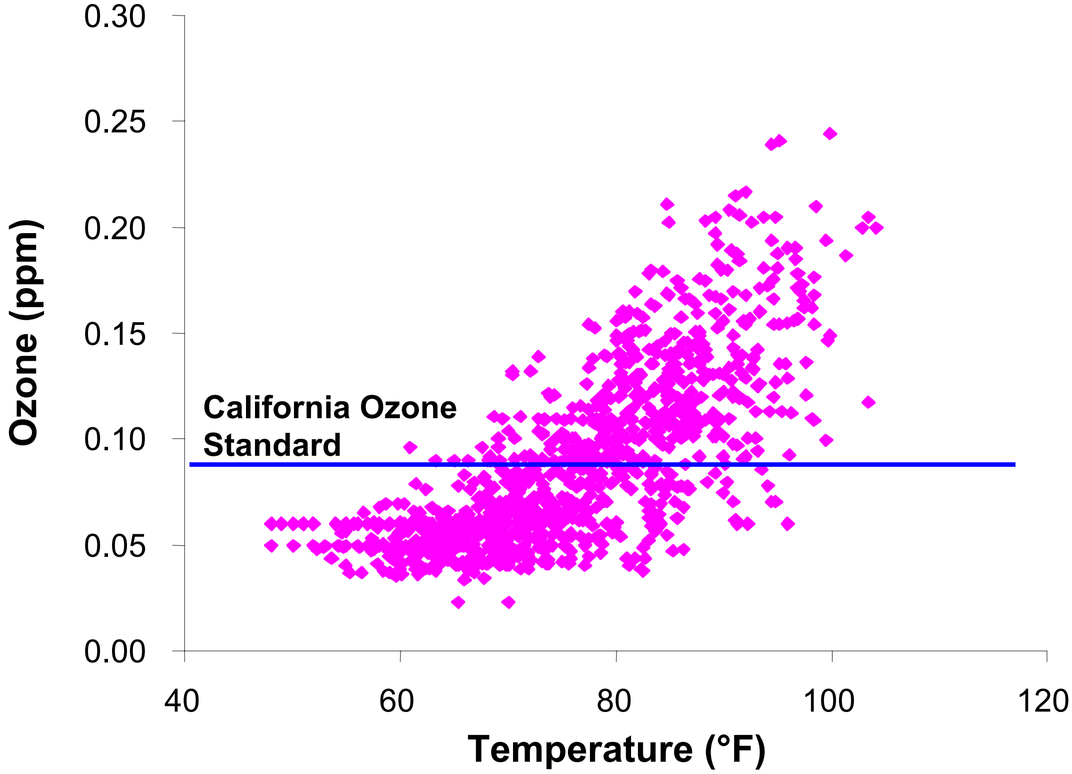


Figure 1-12. Hotter days lead to higher emissions and more smog, Los Angeles Ozone Levels (1995-1998)

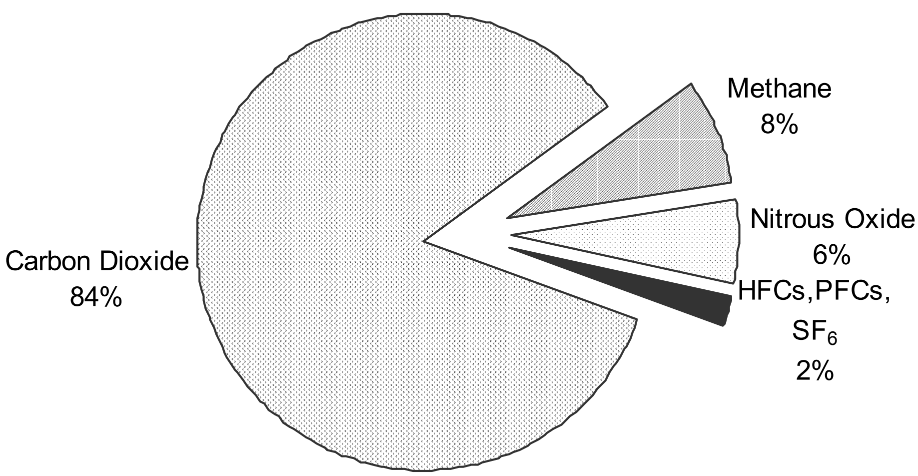


Figure 1-13. California GHG Emissions in 1999 Excluding Marine Bunker Fuels[6]

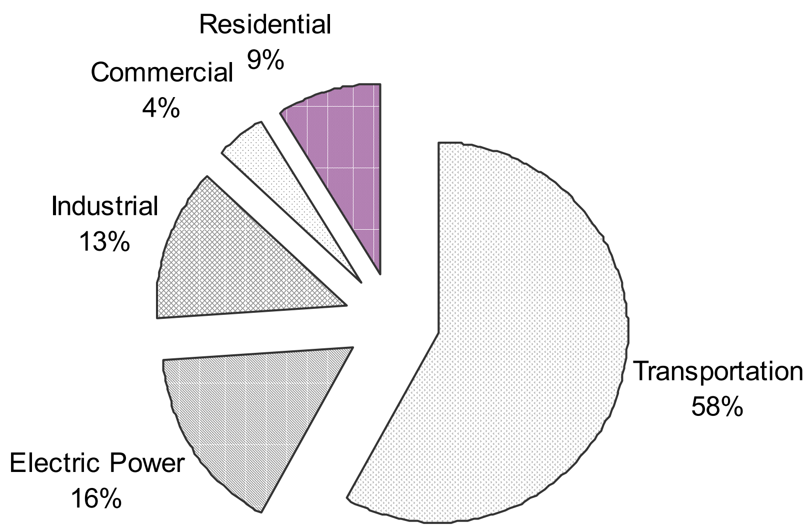


Figure 1-14. Carbon Dioxide Emissions from Fossil Fuel Combustion by Sector for 1999[3].

combustion CO_2 and the warming affect of CO_2 is about 84 percent of the state's total GHG warming impact.

1.2 Economic Impacts

In recent years, California motorists have witnessed rapid spikes in gasoline prices when supply has been abruptly curtailed, usually by unexpected disruptions at one or more refineries. A simplified version of the California gasoline market can be described using supply and demand diagrams to help understand these price spikes.

First, Figure 1-15 portrays the price relationships between supply and demand for the gasoline market in the short-run, assuming no imports. The slope of the gasoline demand curve is extremely steep (inelastic). This means that gasoline demanded does not change significantly with a change in price. The inelastic response occurs because California motorists have no convenient or viable alternative to gasoline for transportation. The gasoline supply curve is relatively flat (elastic) until refinery capacity is approached; at which point the curve becomes very inelastic. Without imports, the equilibrium price of gasoline would be P_0 with a quantity sold of Q_0.

[6] Energy Commission Staff Report, November 2002: *Inventory of California GHG Emissions and Sinks: 1990-1999.*

The availability of imports changes the picture by making the supply curve more elastic, as shown in Figure 1-16. Before price can reach P_0, sellers of gasoline in California find it profitable to import gasoline at some price below P_0, such as P_I (this assumes that at least some refineries outside of the state can provide California RFG at a price below P_0). At price P_I, Q_D is supplied by in-state sources and Q_T is the total amount of gasoline sold. The difference, $Q_T - Q_D$,

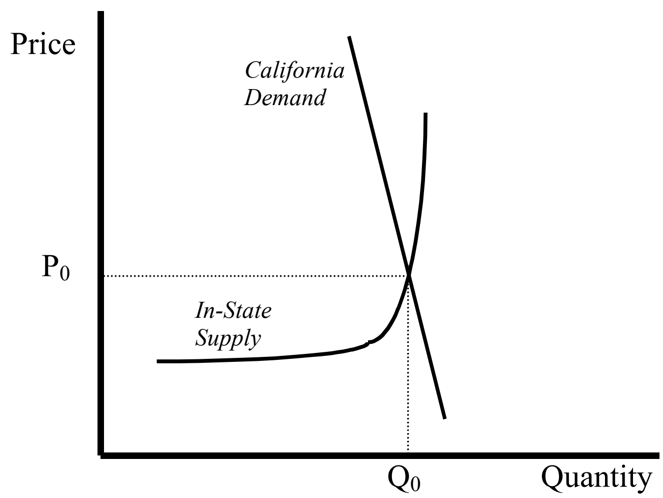


Figure 1-15. California's Gasoline Market without Imports

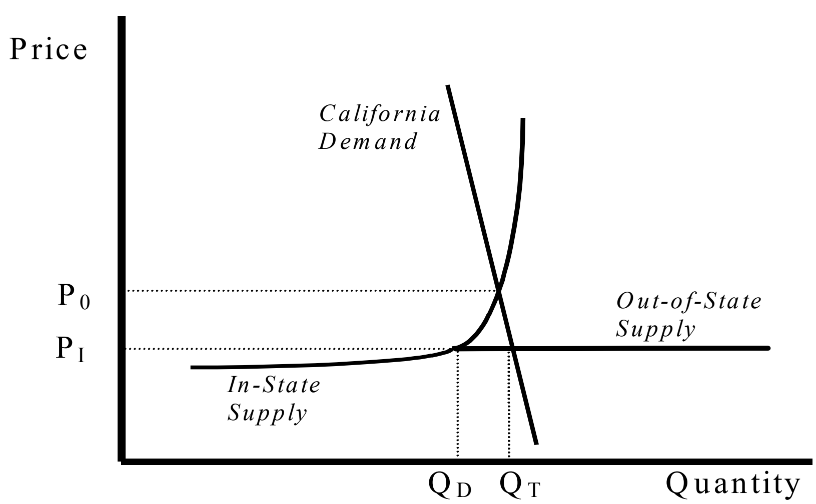


Figure 1-16. The Gasoline Market in California Including Imports

is the amount of imports. The supply curve for gasoline is now the in-state supply up to price P_I, at which point it becomes much more elastic, corresponding to out-of-state supply.

It is important to note that this new "composite" supply curve is *not* a short-run schedule, since any increase in imports cannot occur immediately. Sources for gasoline meeting California specifications must be found and the fuel must be shipped to the state.

Because imports are fixed in the short-run (i.e., the volume of imports can not readily be increased), refinery disruptions in California can lead to price spikes. This is shown in Figure 1-17. A refinery disruption has shifted the in-state supply curve to the left, represented by the dashed line. Gasoline price rises to P_S, where the gap between the new in-state supply curve and the demand curve is $Q_T - Q_D$, the amount of (fixed in the short-run) gasoline imports. Eventually, as gasoline imports increase or the refinery problem is repaired, price falls back to P_I.

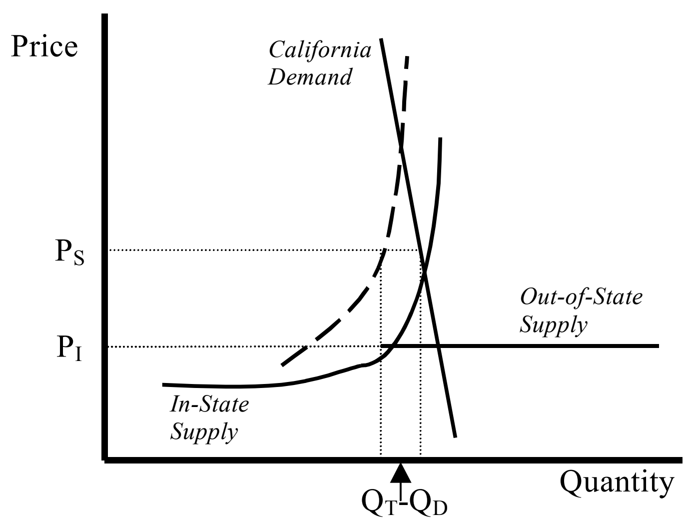


Figure 1-17. A Price Spike in the California Gasoline Market

The shapes of the in-state supply and demand curves dictate the severity of the price spikes. Since California refineries are producing at near capacity, gasoline suppliers are operating on or close to the steep portion of the in-state supply curve. A given supply disruption will, all else equal, have a greater effect on short-run price than would be the case with a more elastic supply. Similarly, a very steep demand curve means a greater price impact from a given disruption, all else equal.

Moderating the market's price response whenever a supply disruption occurs can reduce price volatility. This can be achieved if demand or supply or both were made to be more elastic. In the case of demand, elasticity could be increased through greater availability of substitutes for gasoline. In the case of supply, elasticity could potentially increase in three ways. First, an increase in refinery capacity could extend the flat portion of the in-state supply curve. Second, a reduction in demand (a leftward shift in the demand curve) could result in an equilibrium point (intersection of supply and demand) at a more elastic portion of the in-state supply curve. Third, supply-side measures could be implemented, as discussed below.

1.3 Outlook for California

In the next few years, absent major geo-political events, the prices of gasoline and other refined petroleum products will be affected most significantly by short-run conditions within the state (i.e., price volatility). In the near term (2002-2007), it is not possible to significantly reduce demand for gasoline and other petroleum products without extensive price increases or the adoption of draconian measures to reduce travel demand. Supply-side measures can serve to dampen volatility, and demand measures can reduce the economic impact of the volatility on consumers to a limited degree. Candidate supply-side measures for implementation within the next five years include:

- A state strategic fuel reserve.
- A more liquid forward market for gasoline in California.
- An improved permitting process to facilitate infrastructure investments.

A separate Energy Commission staff analysis will investigate the costs and benefits of these measures.

During the mid-term time period, California is expected to be importing an increased percentage of its gasoline from outside of the state, unless other domestic sources become available or significant demand measures have been implemented. Since a given in-state refinery would produce a lower percentage of total gasoline used in the state, increased imports could serve to reduce the degree of price volatility prevailing in California today. However, this improvement may then be exchanged for greater vulnerability to major supply disruptions outside of the state.

In the long-term, beyond 2020, many experts predict that the effects of worldwide petroleum depletion will begin to affect prices. If clear signs of depletion become apparent, the supply curve (including the in-state and out-of-state portions) shown in Figure 1-16 would begin to shift upward. As a result, California could begin to face significantly higher prices for petroleum products. Ultimately, the petroleum price increases may allow greater market opportunity for alternative sources of transportation fuel to compete economically. In this timeframe, demand-side measures previously implemented would serve to ease this burden, as would measures undertaken to ease the transition to alternative fuels.

1.4 Report Organization

This report presents the completed costs and benefits analysis of petroleum reduction options that lead to a possible strategy and recommended goals on reducing California's petroleum dependency. An overview of the cost benefit analysis is provided in Section 2.

This report summarizes the result of three tasks that were undertaken and led by either the Energy Commission or ARB. Section 2 of this report provides an overview of the entire analysis methodology. The first step of the analysis, performed by the Energy Commission, was a forecast of on-road transportation fuel demand through 2030. This forecast demand is defined as the "business as usual" baseline. Subsequently, the Energy Commission led a task (Task 3) to assess the non-environmental direct costs and benefits of various options to reduce petroleum demand from on-road transportation vehicles. The amount of gasoline and diesel fuel displaced compared to the baseline, the consumer costs and benefits, and the change in government revenue were determined for each of the options considered. The results of this analysis are presented in Section 3.

For each petroleum reduction option, the ARB led an effort to quantify the secondary benefits of reducing petroleum consumption including air quality, global warming, and water pollution impacts. The environmental benefits were then translated into monetary terms. The environmental benefit analysis is presented in Section 4 of this report. Also presented in Section 4 is an assessment of the economic costs associated with petroleum dependency. The combined results of these analyses are summarized in Section 5 of this report, along with an assessment of the economic impact of various strategies to reduce petroleum dependency.

The combined results in Section 5 were used to devise a strategy and suggest a petroleum reduction goal as directed by AB 2076. The strategy and goal are presented in the summary report entitled, *Reducing California's Petroleum Dependence*.

2. Cost and Benefit Methodology

To develop a logical strategy and to form the basis of recommended goals, the Energy Commission and ARB employed a cost and benefit approach to examine the relative merit of various technologies and methods to reduce the state's petroleum dependency. Because nearly three-fourths of the state's transportation fuel demand results from on-road vehicle use, this report focuses on gasoline and diesel fuels. The vast majority of on-road vehicles are light-duty cars and trucks (gasoline vehicles) and heavy-duty trucks (diesel vehicles).

An important goal of this analysis was to estimate in a quantifiable manner the possible benefits that more advanced technologies could provide, including reduced demand for gasoline and diesel and reduced impact to California's environment and economy.

The first step of this cost benefit analysis was to estimate the baseline conditions over the analysis period. A summary of the baseline projections and assumptions is provided in Section 2.1. This is followed by an overview of the cost and benefit analysis in Section 2.2.

2.1 Baseline Projections and Assumptions

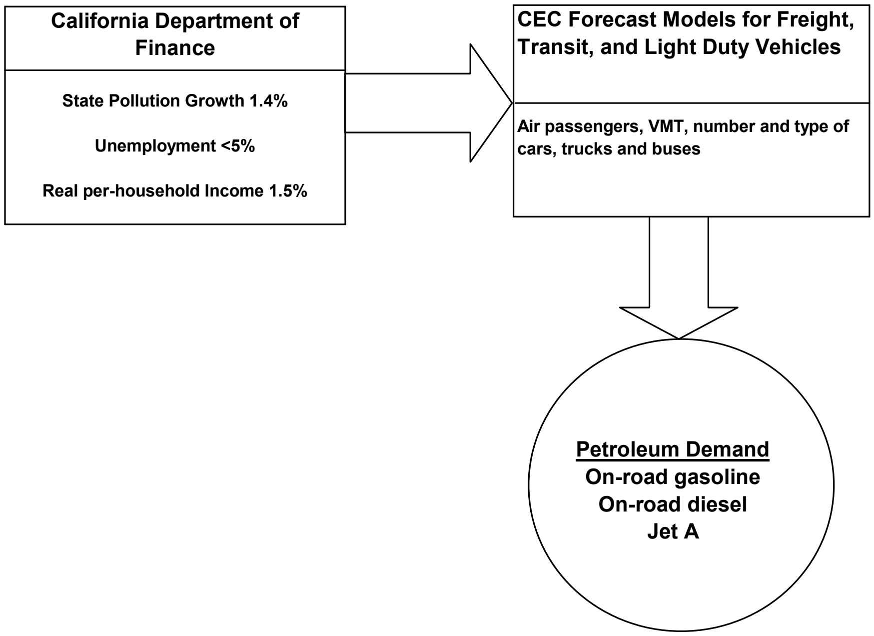
The Energy Commission was tasked to develop the baseline fuel demand projection for this study. The Energy Commission used their established forecasting techniques to develop the baseline projections. The schematic in Figure 2-1 illustrates some of the key assumptions and data used to make the projections. California Department of Finance data on projected population growth, unemployment rate, and real per-household income were used in the forecasting models to predict: vehicle miles traveled; numbers and types of cars, trucks, and buses; and petroleum demand.

2.1.1 Time Frame

Because change in the state's transportation system and successful deployment of new technologies may require decades, the analysis timeframe of 2000 to 2050 attempts to capture the far reaching possibilities of measures that appear cost-effective in the near-term and those that merit longer-term investment. However, the conditions and key values that control the results of the forecast become increasingly less certain beyond 2020. The forecast to 2020 was extrapolated to 2030 using the annual growth rates shown in Figure 2-1. The forecast beyond 2030 to 2050 was determined by linearly extrapolating from 2030. These uncertainties are also displayed in Figure 2-1.

2.1.2 Demographics and Fuel Used

The vehicle population in California is expected to increase faster than the rate of population growth. California's population is expected to increase by about 98 percent between 2002 and 2050, from 33.8 million to 67 million. The expected 2050 vehicle population is about 47 million, a 104 percent increase from the 2002 vehicle population. Vehicle miles traveled are also projected to grow faster than the population growth rate due to rising per capita income.



Linearly Extrapolated from 2030 →
Extrapolated with Growth Rate →
Projected with Growth Rate ↔

California Transportation Characteristics	2000	2020	2030	2050	% Growth to 2020	
Demographs						
Population (million)	33.8	44.6	51.3	*67.7*	1.4	
Number of Light Duty Vehicles (million)	22.8	31.6	37.3	*47*	1.65	
Vehicle Miles Traveled (VMT[a]) (billion mi/yr)	295	421	504	*541*	1.8	
Fuel Used						
On-Road						Lower Heating Value
Gasoline (billion of gallons)	14.2	19.5	22.9	*30.1*	1.6	112,000 Btu/gal
Diesel (billion of gallons)	2.6	4.2	5.3	*7.8*	2.4	127,500 Btu/gal
Combined Gasoline+Diesel (billion of gallons gasoline equivalent gallons)	17.2	24.3	28.9	*39.0*		
Jet Fuel	5.1	10.0	13.9	*19.2*	3.4	
Light Duty On-Road Fuel Economy						
Gasoline (mpg)	21.2	21.2	21.2	*21.2*		
					Gasoline and Diesel Standard Deviation	
Fuel Prices (2001$)						
Crude Oil ($/bbl)	22.5	22.5	22.5	*22.5*	Low	High
Gasoline ($/gal)	1.64	1.64	1.64	*1.64*	1.47	1.81
Diesel ($/gal)	1.65	1.65	1.65	*1.65*	1.48	1.82

[a] VMT includes light duty vehicles, freight, and transit. Light duty VMT about 95% of total VMT and Light duty VMT varies from 274 billion miles per year in 2000 to just under 390 billion miles per year in 2020.

Figure 2-1. Baseline Projections and Analysis Assumptions

At the projected annual growth rates of 1.6 percent and 2.4 percent for gasoline and diesel, respectively, the total demand for these fuels is expected to more than double by 2050. Gasoline demand is forecast to grow from 14.2 billion gallons in 2000 to 22.9 billion gallons in 2030 and slightly over 30 billion gallons in 2050. Diesel demand is expect to grow from 2.6 billion gallons in 2000 to 5.3 billion gallons in 2030 and 7.8 billion gallons in 2050.

If new vehicle fuel economy does not improve beyond the current federal standards for corporate average fuel economy, the forecast projects that the average light-duty vehicle on-road fuel economy will remain near 21.2 mpg throughout the forecast period to 2020. This value was then also held constant through 2050. Light-duty trucks will continue to increase as a fraction of California's light-duty vehicle stock due primarily to the continued growth in sales of the smaller sport and cross utility vehicles.

2.1.3 Fuel Price Assumptions

For 2000 to 2020 the Energy Commission assumes long-term gasoline prices will be $1.64 per gallon and diesel fuel prices at $1.65 per gallon (2001$). These prices assume oil prices will be fairly well behaved at $22.50 per barrel. The gasoline and diesel prices account for the price premium of importing refined product into California and the margin necessary to expand not only the existing fueling infrastructure but also the infrastructure for increasing imports of refined products. For lack of better predictive tools and dependable input parameters that extend beyond 2020, these price assumptions where also used in the analyses through 2030.

To investigate the relative importance of our baseline fuel prices for gasoline and diesel, one standard deviation in price was used to derive a low and high price range. For gasoline, this was about 17 cents per gallon resulting in a low of $1.47 and a high of $1.81. A similar range was used for diesel.

For convenience throughout this volume of the report we have combined the volumes of gasoline and diesel demand and express the resulting total in units of gallons of gasoline equivalent. This is based on the energy contents listed in Figure 2-1 (lower heating values) for gasoline and diesel.

2.2 Overall Analysis Methodology

The desired result from the analyses was comparative estimates of net benefits from various measures to reduce gasoline and diesel consumption. The overall methodology was divided into three major tasks as show in Figure 2-2. Task 2 produced the baseline projections described in the previous section. This projection provided the following inputs to the Task 3 and Task 1 efforts:

- Number of new vehicles by type by year; total vehicle population and total types of vehicles by year
- Fuel economy of new and existing vehicles by type
- Vehicle miles traveled by vehicle type and age of vehicle
- Emissions of new vehicles (light- and heavy-duty)
- Fuel prices for gasoline and diesel

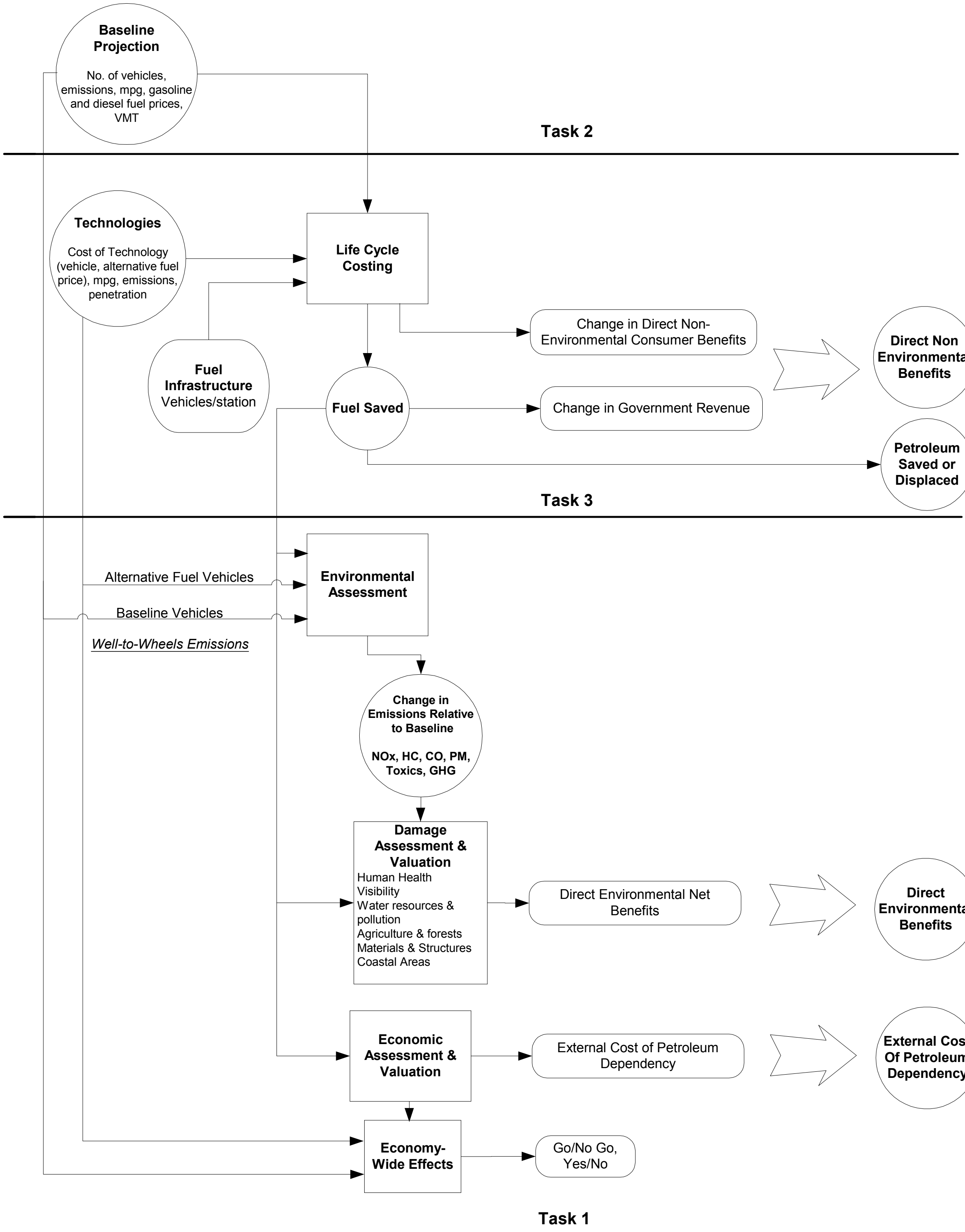


Figure 2-2. Overall Petroleum Dependency Analysis Methodology

For each option evaluated, the total estimate of the net benefit from reducing gasoline or diesel consumption was summed from Task 1 and Task 3 results. Task 3 estimated the marginal costs and benefits to consumers and government of a variety of fuel efficiency, petroleum displacement, and pricing options. The Task 3 results on petroleum displacement and consumption and changes in miles traveled were used in Task 1 to determine the marginal changes in emissions and other environmental effects, as well as the change in the external costs of petroleum dependency. Task 1 placed monetary values on these changes. The Task 3 results were also used to estimate economic impacts to California of various petroleum reduction strategies and to estimate the possible economic value of reducing petroleum use in California.

The principal results of the analyses were described with the following metrics:

- Direct Non Environmental Net Benefit (DNNB), which is the sum of Direct Non Environmental Consumer Benefits and the impact on Government Revenue, expressed in 2001$
- Petroleum reduced through fuel efficiency options or displaced with alternative fuels, expressed in gallons of gasoline equivalent
- Direct Environmental Net Benefit (DENB), expressed in 2001$
- External costs of petroleum dependency (ECPD), expressed in 2001$

2.2.1 Task 3 — Direct Non Environmental Net Benefits (DNNB)

This effort estimated the marginal cost and benefit of advanced gasoline or diesel technologies and pricing options compared to the operation of baseline vehicles. This was done using a life cycle costing methodology that incorporated the cost and performance of the advanced technology and compared this to the cost and performance of the baseline technology. For example, the incremental cost for improved vehicle fuel efficiency was compared to the value of its fuel savings over the lifetime of the new technology vehicle. Positive results from the lifecycle costing are called benefits.

The life cycle methodology employs a discounting element to account for society's time-based value of costs and benefits. When expenditures and corresponding benefits occur in the future, their dollar value from today's point of view decreases with time. For example, a dollar received today is valued more than a dollar to be received five years from now. In this analysis, a discount rate of 5 percent was used since this rate is commonly utilized in California for assessing different governmental policies.

The methodology also determined the change in government revenue associated with each option. For example, in the case of improved fuel economy, the change in government revenue was measured by the loss in tax revenue associated with reduced sales of gasoline or diesel fuels. Some options specify a government expenditure that would reduce funding for an existing program. Such a cost is treated as a revenue loss.

For the fuel substitution options, the methodology employed some simplifying assumptions to allow for a more consistent comparison within this category. Unfortunately, this approach makes it more difficult to compare this category with the efficiency and pricing options. Because the alternative fuel options are not at the same stage of development or commercial standing, these options were evaluated as if they achieved a more uniform and mature commercial status. Estimates were made on their performance and vehicle and infrastructure costs assuming that current research and development goals were successfully attained. The deployment of vehicle technologies using these fuels was then assumed to reach a market penetration level equal to 10 percent of new vehicle sales by 2020 or 2030, depending on the current status of the technology. This market size allowed for sufficient economies of scale to make reasonable estimates for vehicle and infrastructure costs. The current taxation rate for each of these alternatives was assumed to remain unchanged throughout the analysis period. Additional rationale is provided in the appendix for Task 3[7] on market penetration, the deployment of fuel infrastructure to serve these vehicles, and the fuel prices that result.

If the alternative fuel technologies were projected to cost more than the conventional technologies, then the assumed market penetration level would likely require additional financial support or incentives to offset the higher consumer cost. However, the economic effect of a specific implementation plan would also affect the overall economic evaluation for the specific option. Depending on the incentive mechanism, the net benefit may further decline because of deadweight losses.[8]

The overall results of the Task 3 analyses were the monetary benefits and fuel saved or displaced. The DNNB was summed over various time periods: 2000-2010, 2000-2020, and 2000-2030 and discounted by 5 percent per year. Cumulative fuel savings were also determined for these periods. For alternative fuel technologies, both the gasoline and diesel fuel saved and the amount of alternative fuel used was determined.

2.2.2 Task 1 — Direct Environmental Net Benefits and External Cost of Petroleum Dependency

This task quantified the additional value that might result from reducing petroleum use in California due to avoided impacts. For example, decreasing the amount of fuel distributed in California reduces the number of tanker trucks distributing fuels and reduces the number of stations dispensing fuels. Reducing these events reduces emissions. Also, researchers have identified that dependency on petroleum adds burdens to the U.S. and California economies. These costs are external to the costs included in the price of gasoline or diesel and, therefore, need to be included in a cost benefit analysis.

[7] *Appendix C: Petroleum Reduction Options (Task 3)*, January 2003.

[8] In economic analyses, a non-market action that reduces the price of a product or service may produce a societal cost called a deadweight loss. In the case of a government incentive, the amount paid out (a cost) would exceed the benefit gained by the recipients.

Direct Environmental Net Benefits

Direct environmental net benefits (DENB) were determined by estimating how changes in emissions affect the environment and then estimating how these changes affect the satisfaction derived by individuals from the environment. In most cases a reduction in emissions will lead to a reduction in exposure. This reduction in exposure reduces the mortality and morbidity risks to humans and animals and also reduces other damages to plants and materials. Reducing emissions generally improves the environment and this results in a benefit to humans. This benefit can be estimated and compared for various technology options.

To estimate these benefits, an avoided damage approach was employed. This approach is widely used by organizations involved with environmental policy-making and well accepted in the literature. The emission changes due to a particular option were first determined. These changes were then correlated to changes in exposure, their effect on health and welfare, and the economic value of the avoided effects.

Another element of the analysis that is also well recognized involved the use of transfer methodologies. This approach accepts the transfer of similar benefit analyses found in the literature by using monetized damage values normalized by the direct emissions determined for a specific option.

Transfer methodologies use existing values for dollar damages per ton of pollutant to approximate the exposure, subsequent human health and ecosystem changes, and damage costs of these changes. Damage costs are determined using the concept of willingness to pay. For example, individuals value their health and would pay to avoid or reduce risks of mortality and morbidity. Several recent studies have focused on the external costs and benefits of transportation and have performed very detailed damage analyses that then provided dollar per ton damage estimates consistent with the conditions of this study. Using these transfer factors, damage or benefit estimates could be determined from the direct emission reductions for each advanced technology compared to the baseline technologies as shown in Figure 2-2.

Since the timeframe for this analysis was mostly long term (greater than 10 years), vehicles were assumed to meet the most stringent standards existing or proposed in the near future. For light-duty vehicles we assumed that all vehicles at a minimum would achieve partial zero emission vehicle (PZEV) standards. For heavy-duty vehicles we assumed that all vehicles would achieve the currently proposed ARB and EPA heavy-duty engine standards scheduled to be implemented starting in 2007. Table 2-1 shows these standards and our estimate of the resulting on-road emissions.

Baseline and advanced technology emission estimates included all California related emission events for criteria and toxic emissions (e.g. NO_x, HC and PM) and all related emission events for GHG emissions (CO_2, N_2O, and CH_4). The GHG emissions events were estimated using a typical wells-to-wheels analysis. Since criteria pollutants and toxics impact local regions, these emissions were neglected outside of California. Conversely, GHG emissions affect global climate change, therefore all GHG emissions were accounted for even if they occurred out of state. Emissions associated with vehicle production, recycling, or scrapping were not included.

Table 2-1. Assumptions on Future Vehicle Emissions

	Light-Duty Vehicles		Heavy-Duty Vehicles	
	Standard (g/mi)	In-use (g/mi)	Standard (g/bhp-hr)	In-use (g/mi)
NO_x	0.02	0.024	0.2	0.89
NMHC Diesel	0.01	0.029 0.007	0.14	0.221
CO	1.0	0.4	15.5	2.07
PM diesel Gasoline	0.01	0.01 0.002	0.01	0.35

Damage assessment was performed using the aforementioned transfer methodology. The dollar damage per ton values were estimated for typical California conditions. However, the global warming dollar per ton value was estimated based on world damages and emissions. Also included in the global warming damage value is the external cost of petroleum dependency, which was estimated based on U.S. conditions. Changes in emissions and transfer dollar damage per ton pollutant estimates were used to determine damages or reduction in damages for endpoints such as premature mortality, visibility, water resources and pollution, agriculture and forests, materials and structures, and coastal areas. Ozone, fine particulate, water pollution, and global warming cause the majority of the damages.

For each advanced technology option, changes were determined for upstream and tailpipe emissions. Damages were then assessed for the various human health and other ecosystem changes. These estimates were determined over the vehicle lifetime and their value discounted at 5 percent per year, yielding DENB. DENB were summed over the same time periods as DNNB: 2000-2010, 2000-2020, and 2000-2030. The results of DENB are presented in terms of criteria pollutants, global warming, and water pollution. Toxic emission benefits were estimated but damages were not determined due to lack of transfer dollar damage per ton toxic pollutant estimates.

External Cost of Petroleum Dependency

Certain costs related to U.S. petroleum dependence are considered external[9] because they are borne by the citizens, but are not reflected in the market price of crude oil. The external costs that have been identified in the literature fall into two broad categories: military costs and economic costs. Military costs include defense expenditures by the U.S. that can be attributed to securing Middle East crude oil supplies and expenditures for the Strategic Petroleum Reserve (SPR). Economic costs include monopoly rent transfers from U.S. consumers of crude oil to foreign oil producers, long-run reductions in U.S. Gross Domestic Product (GDP) attributable to

[9] It should be noted that there is no universal agreement in the literature about which costs should be considered external.

OPEC's ability to raise crude oil prices above competitive levels, and short-term macroeconomic effects of crude oil price episodes.

In this analysis, an estimate of the external costs of petroleum dependence was derived from and based upon a review of recent empirical work in this area. This estimate was then converted to a cost per gallon of gasoline and multiplied by the amount of gallons reduced to give the benefit of reduced external petroleum dependency costs for each option evaluated. Note that this benefit represents a total for the U.S. as a whole. The actual benefits accruing to California would be smaller than the amounts reported.

General Equilibrium Model

A general equilibrium model that considered the whole California economy compared to the rest of the world was employed to assess the impacts of petroleum reduction strategies on the various sectors of the state economy. This analysis provided results at the sectoral level for output, employment, and income.

Other Costs

There are other potentially important external impacts that are associated with driving *per se*, such as public health effects, un-internalized accident costs, and roadway congestion. Thus, if a policy measure influences the total amount of driving in California, it could have an impact on social welfare. A measure that reduces vehicle miles traveled (VMT) may provide benefits to California in the form of reduced external costs. On the other hand, any measure that reduces the cost of driving (e.g., improved average vehicle efficiency) could increase VMT. The latter action may lead to increases in the external costs related to driving.

An increase in VMT due to a reduction in the cost of driving is referred to as the "rebound effect." The Energy Commission and ARB staffs are currently involved in a study to determine the significance of this effect. The study will also attempt to measure the external costs associated with driving. The current analyses do not include these potential cost elements.

3. Petroleum Reduction Options

As discussed in previous sections, there are several compelling reasons why California should endeavor to reduce its rate of petroleum fuel consumption. The Energy Commission has performed an extensive analysis of a range of options to decrease California's dependency on petroleum products for transportation. The methodology for the analysis was presented in Section 2 of this report. This section of the report summarizes the results of the Energy Commission's Petroleum Reduction Options analysis.

Four different groups of options were considered to reduce California's dependence on petroleum: fuel efficiency, fuel substitution, pricing, and other options. Only the fuel efficiency and fuel substitution results are presented in detail in this section. The integrated results for the pricing options are presented in Section 5 of this report. The other options are not included because economic results were not quantified.

While each option was considered for a range of fuel prices ($1.47 to 1.81 $/gal for gasoline and 1.48 to 1.82 $/gal for diesel), only the intermediate fuel price of $1.64 per gallon case is presented here. For a detailed description of the base case and the results for all of the petroleum reduction options, please refer to the Energy Commission report entitled Appendix C: Petroleum Reduction Options (Task 3).

Figure 3-1 provides the base case on-road demand for gasoline and diesel fuel that can not be met by California refineries. By 2010, an annual shortfall of 2 billion gallons is predicted. In 2030, the annual shortfall increases to 9.5 billion-gallons. It is estimated that 18 billion gallons of gasoline and diesel will need to be imported by 2050 to meet the on-road transportation demand.

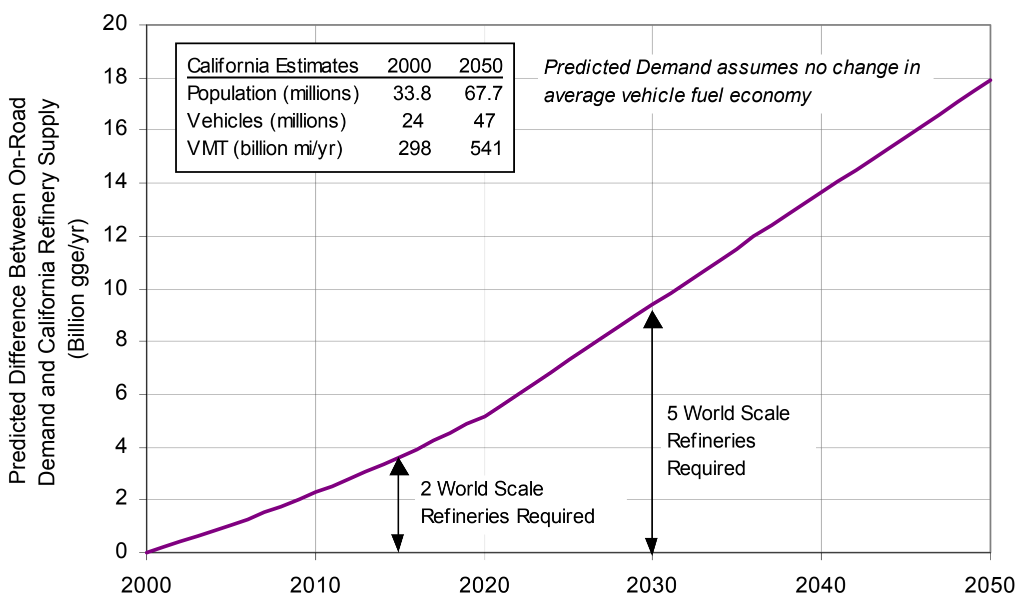


Figure 3-1. Predicted Import Requirements for On-road Transportation

The following subsections provide a summary of the results for the fuel efficiency and fuel substitution options. The DNNB is the only economic value presented in this section. Economic benefits derived from environmental and economic impacts are addressed in Section 4 of this report.

3.1 Fuel Efficiency Options

Use of vehicle and engine technologies to improve light-duty vehicle fuel economy can provide the largest gasoline reduction of all of the options considered in this analysis. Moreover, many of the fuel efficiency scenarios under this option also have positive DNNB. The estimated reductions from the base case demand forecast in 2030 range from 0.02 to 11 billion gallons per year. The fuel efficiency options evaluated include:

- Light-Duty Gasoline Vehicle Options:
  - Improved fuel economy
  - Fuel efficient replacement tires and tire inflation programs
  - Fuel efficient government fleets
  - Improved vehicle maintenance practices
  - Diesel replacing gasoline
- Improved Fuel Economy for Medium- and Heavy-Diesel Vehicles

For the light-duty fuel economy scenarios, the Energy Commission used fuel economy analyses performed by the American Council for an Energy-Efficient Economy (ACEEE)[10], the National Research Council (NRC)[11], and Energy and Environmental Analysis (EEA)[12] to create the ten scenarios shown in Table 3-1. These scenarios assume national implementation to allow use of the resultant cost targets. A California only scenario would result in higher unit vehicle costs. The two ACEEE hybrid cases assumed that the technology cost would remain constant over time. The ARB hybrid cases are technologically identical to the ACEEE hybrid cases, but employ higher initial cost estimates for battery replacement that are then expected to decrease along with other component costs rather than remain constant over time.

In all of the fuel economy scenarios, it was assumed that the improved technology vehicles would enter the market in 2008 and would be linearly phased in over seven years. By 2014, the average new vehicle fuel economy would equal the on-road levels shown in Table 3-1. It is recognized that the efficiency technologies used for each case may not be ideally applied to all

[10] *Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015*, ACEEE, April 2001.

[11] *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, National Academy of Sciences, 2002.

[12] *Analysis and Forecast of the Performance and Cost of Conventional and Electric Hybrid Vehicles*, Energy and Environmental Analysis, Inc., February 2002 (Final Report to the California Energy Commission)

Table 3-1. Summary of Light-Duty Fuel Efficiency Scenarios Evaluated

Scenario	On-Road[a] MPG	Description of Fuel Economy Technologies	Technology Breakthroughs Required?
ACEEE Moderate	30	Mass reduction, streamlining, efficient tires, 50 kW/l engine w/o direct injection, improved transmission, integrated starter-generator.	None, but not widely implemented to date.
ACEEE Advanced	34	Same as moderate but more mass reduction, 55 kW/l direct injection engine	SUV mass reductions may require new materials
ACEEE Mild Hybrid	40	Same as advanced, but a hybrid electric power train & electric power for 15% of peak power.	None
ACEEE Full Hybrid	45	Same as mild hybrid but uses electric power for 40% of peak power.	Need cost reductions of hybrid components
ARB Mild Hybrid	40	Same as ACEEE mild hybrid but assumes a more aggressive cost reduction over time.	None
ARB Full Hybrid	45	Same as ACEEE full hybrid but assumes a more aggressive cost reduction over time.	None
NRC Path 1	23	5% weight increase, reduced engine friction, variable valve timing, efficient tires, reduced drag, improved transmission, cylinder deactivation, 42-volt electrical systems.	42-volt electrical systems are emerging.
NRC Path 2	28	Same as Path 1, plus 6-speed auto transmission for larger vehicles, auto shift manual transmissions, continuously variable transmission, intake valve throttling, electric power steering.	valve throttling, auto shift, electric steering are emerging.
NRC Path 3	31	Same as Path 2, with supercharging, engine downsizing, CVT for all classes, camless valve actuation, variable compression ratios, integrated starter-generator, weight reductions for larger vehicles.	Camless valves, variable compression ratios emerging.
EEA	28	Composite and ultra high strength body materials, electric power steering, variable valve timing, cylinder deactivation, advanced torque converter, CVT and electrically shifted manual transmissions, 42 volt hybrids, on-demand electric four wheel drive.	Available and deemed cost effective

[a] EPA fuel economy valuation is 15 percent higher than on-road fuel economy.

13-vehicle classes used to model the existing fleet population. However, other scenarios can be devised that provide equivalent petroleum displacement and DNNB with implementation across selected vehicle classes.

The fuel-efficient replacement tire and tire inflation option is a combination of two programs. A public outreach campaign would be undertaken to recommend that tire inflation be maintained at manufacturer suggested levels and publicize a new tire rating system for rolling resistance. Benefits would also be described to influence consumers to select more fuel-efficient models when replacing original equipment tires.

The efficient government fleet option would require all light-duty government fleets in California to select the most fuel-efficient vehicle in each vehicle class. However, since a large majority of government vehicles are used for emergency services and law enforcement, as many as two-thirds of annual purchases may be exempted from this requirement. It was assumed that this option would go into effect in 2005.

The improved vehicle maintenance option is a state campaign to educate motorists on the benefits of improved maintenance practices. Maintenance activities considered include replacing air filters every other year and replacing the oil and oil filter twice a year. Other maintenance practices such as an engine tune-up would normally be performed on a regular basis due to California's smog check program and are already accounted for under the base case.

The light-duty diesel vehicle (LDDV) option compares the incremental costs and benefits between an average gasoline vehicle and a diesel counterpart. Based upon research and development programs sponsored by the U.S. Department of Energy, the LDDV technology has the potential for fuel economy that is 45 percent greater than a comparable gasoline vehicle. However, the analysis assumes light-duty diesel vehicles meet California's emissions standards, including particulate matter emissions at 0.01 grams per mile. The addition of emission control systems that allow LDDVs to meet these standards would add to the existing higher cost of a diesel vehicle compared to a gasoline vehicle and would decrease its fuel economy.

For the medium- and heavy-duty diesel vehicle fuel economy options, two efficiency scenarios were considered. The lower bound is a nominal fuel economy improvement based on implementation of a national fuel economy standard for the heavy-duty vehicle fleet that does not rely on technology breakthroughs to achieve the standards. The upper bound is based on the U.S. Department of Energy's (DOE) 21st Century Truck Program targets which rely on technology breakthroughs to achieve the efficiency targets. It is assumed that deployment of these vehicles begins in 2008 and sales reach 20 percent of new vehicles by 2030.

Figures 3-2 through 3-4 summarize cumulative DNNB and petroleum displacement results for 2010, 2020, and 2030. The mpg values shown in the legend are on-road average values – EPA rated fuel economy values would be approximately 15 percent higher. In the 2020 and 2030 plots, two values are shown for each hybrid scenario – one for the ACEEE case and one for the lower cost ARB version. The plots show that even modest improvement in light-duty vehicle fuel economy result in significant decreases in petroleum consumption. Moreover, most of these cases result in large positive DNNB in the long-term.

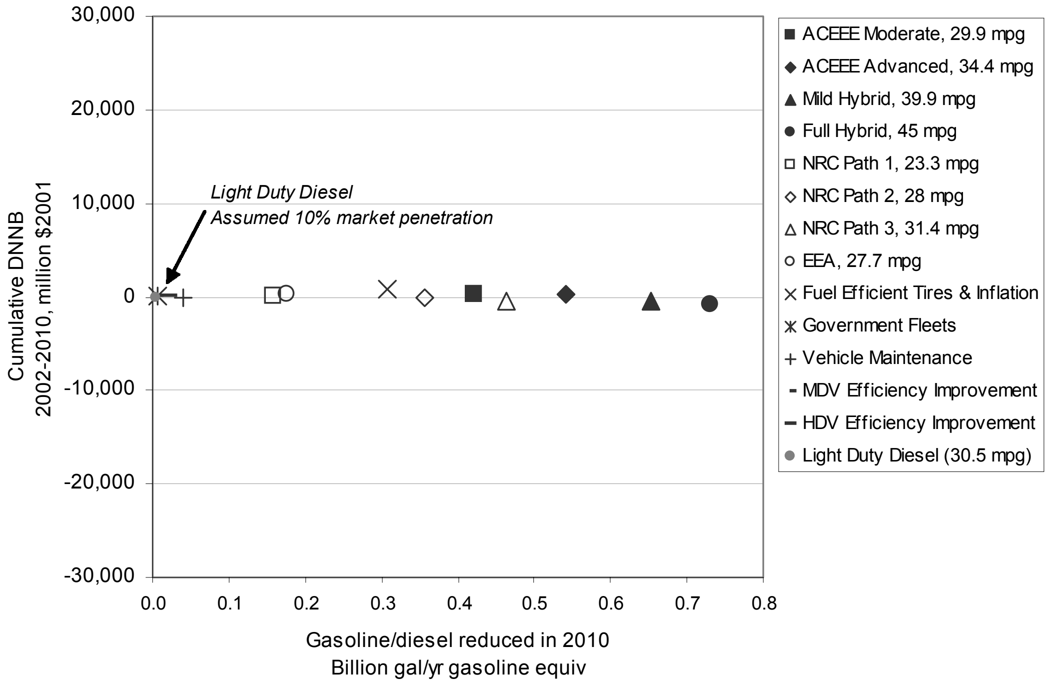


Figure 3-2. Cumulative DNNB vs. Petroleum Reduction in 2010 for the Fuel Efficiency Options and Scenarios

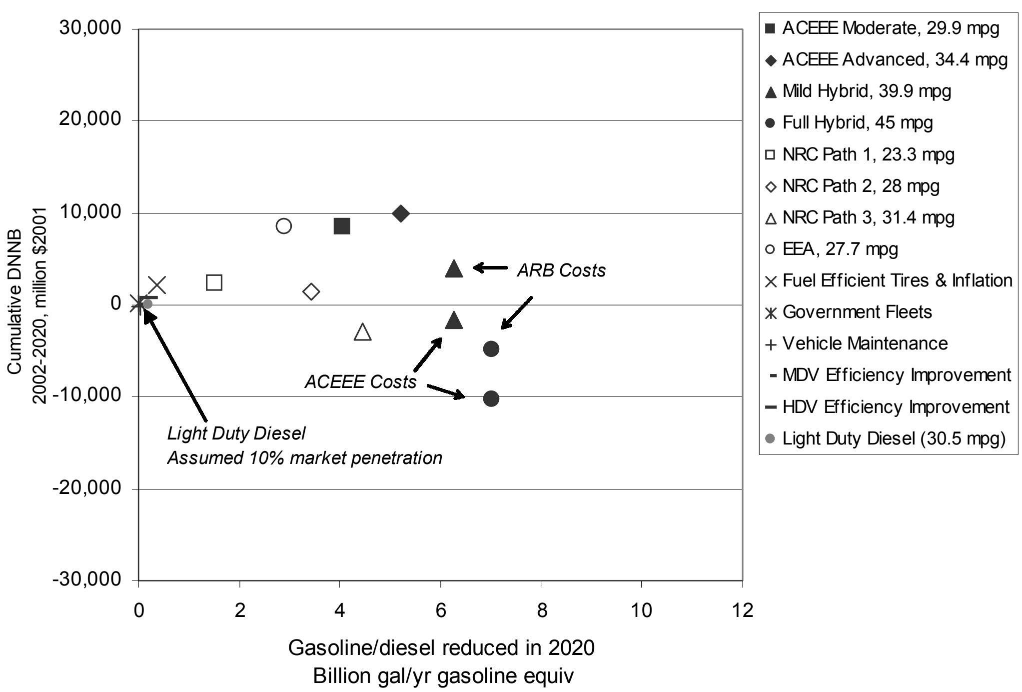


Figure 3-3. Cumulative DNNB vs. Petroleum Reduction in 2020 for the Fuel Efficiency Options and Scenarios

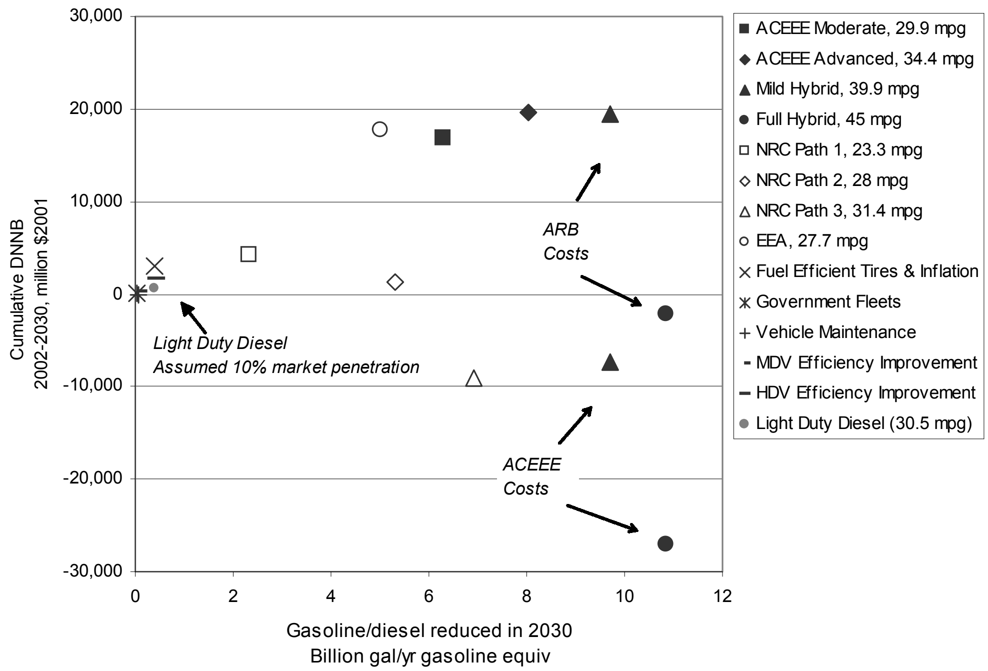


Figure 3-4. Cumulative DNNB as a Function of Fuel Use Reduction in 2030 for the Fuel Efficiency Options and Scenarios

In the near term, use of fuel-efficient tires combined with proper tire inflation provides a small but significant reduction in gasoline consumption with positive DNNB. In 2010, it is estimated that 0.3 billion gallons of gasoline per year could be saved. Because the analysis assumed a constant fraction of consumers would voluntarily participate in the program, the improvement stays relatively constant and the effect is small compared to other options by 2020.

Although the government fleet and vehicle maintenance programs result in small petroleum displacements, the DNNB is positive and implementation of these programs sets a positive leadership example.

Improvements in medium and heavy-duty diesel efficiency result in reductions in petroleum fuel consumption compared to the base case. However, since the population of these vehicles is much smaller than the light-duty vehicle fleet, the reduced volumes are not as large as the light-duty vehicle results. The DNNB is also positive. It is projected that consumption could be reduced by up to 0.7 billion gallons per year by 2030.

Figure 3-5 illustrates that at some point the direct cost of technology for improving vehicle fuel economy exceeds the value of consumer benefit. This figure compares the base case demand forecast to the demand for the 34.4 mpg and 45 mpg options. The corresponding DNNB is noted on the graph. For the 45-mpg full hybrid case, the DNNB for both the ACEEE and ARB cases is noted. The 34.4-mpg option is based on currently available technology and has a significant positive DNNB. The 45-mpg technology is available, but not for all vehicle classes and has a

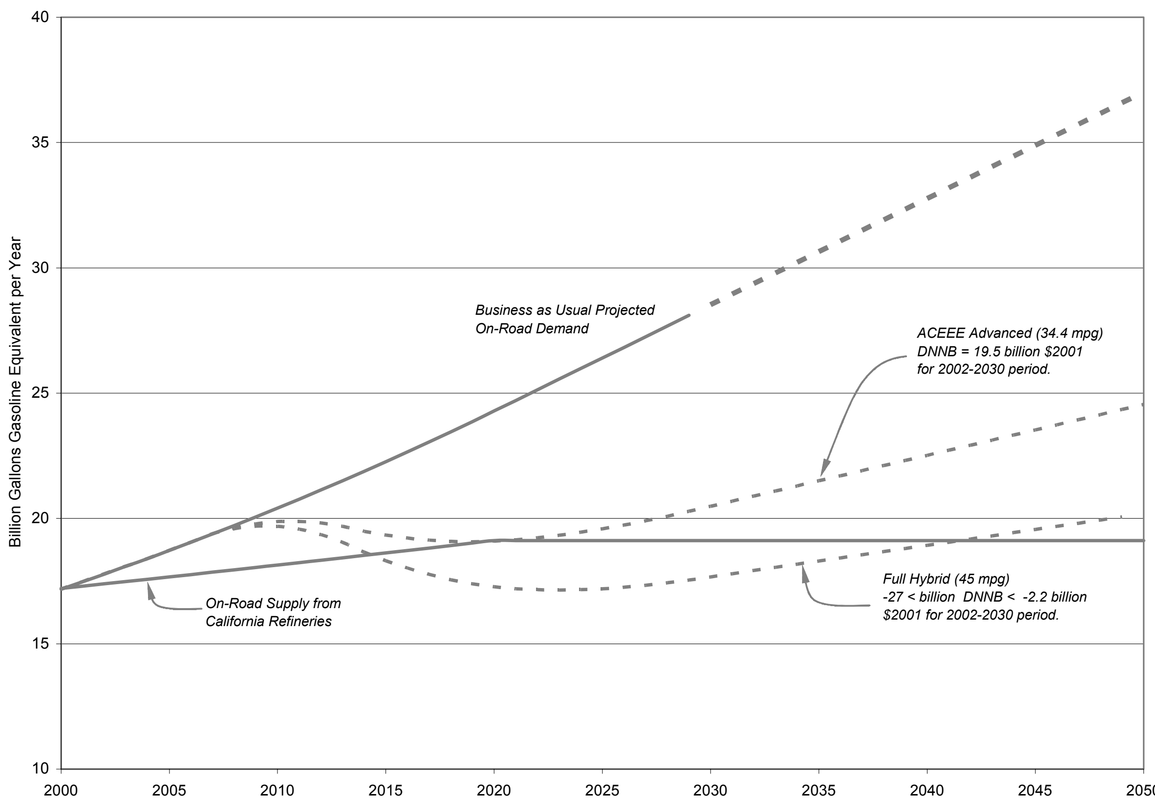


Figure 3-5. Predicted Impact of Selected Fuel Economy Scenarios on California Demand for On-road Transportation Fuels

much lower (negative) DNNB. Thus, even though the higher fuel economy case displaces more gasoline, it does so with a net loss (cost). Despite the large difference in DNNB for the 34.4-mpg and 45 mpg options, the demand reductions are surprisingly close.

Figure 3-5 also shows that fuel demand begins to increase again after about 2020 – when the fuel economy improvements have been completely phased in. This is because the growth in population and VMT increases fuel consumption, eventually negating the gasoline reductions previously achieved.

To produce a positive DNNB, the net consumer benefit must outweigh decreases in government revenue. As shown in Figure 3-6, the 34.4-mpg ACEEE Advanced Technology case has the largest consumer benefit (column A) because it has the highest ratio of gasoline displacement to incremental vehicle cost. The two full hybrid cases, identical except for incremental vehicle cost, have lower net consumer benefit than the Advanced Technology case because the increased fuel savings does not fully offset the significantly higher vehicle costs. With higher vehicle fuel economy, the two hybrid cases have a greater negative impact on government revenue (column B) since the collection of fuel excise taxes is further reduced compared to the Advanced Technology case. When the greater loss in government revenue is combined with their respective net consumer benefit values, the overall net benefit (A+B) for the hybrid cases is not

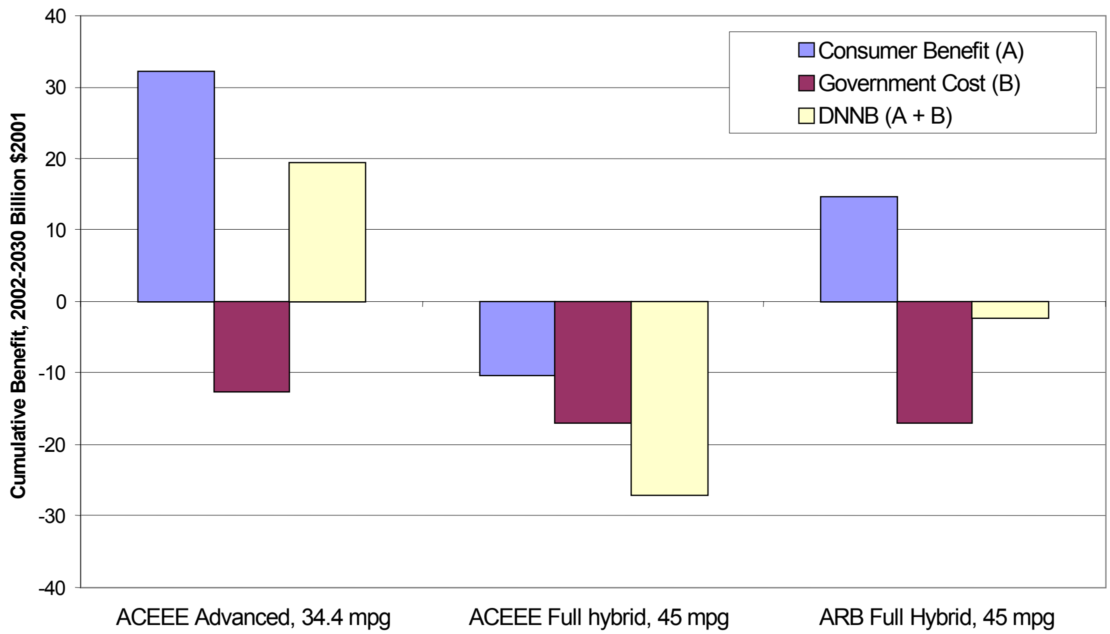


Figure 3-6. Direct Consumer and Government Costs/Benefits for the 45 and 34.4 mpg Scenarios

as positive as the Advanced Technology case. In addition, the net consumer benefit for both full hybrid cases is not sufficient to offset the loss in government revenue and the DNNB is negative for each.

3.2 Fuel Substitution Options

The Group 2 fuel substitution options evaluate the use of alternative fuels for transportation. The specific options considered are:

- Light-Duty Gasoline Vehicle Options
  - Hydrogen Fuel Cells
  - Full Size Electric Battery
  - Grid-connected hybrid electric
  - Compressed Natural Gas (CNG) and Liquid Petroleum Gas (LPG)
  - Alcohol fuels in flexible fuel vehicles (FFVs)
  - 10 percent ethanol blend in RFG3

- Medium- and Heavy-Duty Diesel Vehicle Options
  - CNG and LNG
  - Fischer-Tropsch Diesel
  - Biodiesel

For most of the options considered (fuel cells, full size battery, grid-connected hybrid, CNG and LPG) a maximum market penetration of 10 percent was assumed. This level is consistent with maximum penetration rates of previous alternative fuel programs. Although the actual penetration for the options considered will vary, we selected 10 percent for these options so that they could be compared in a consistent manner. It was also assumed that deployment would commence in 2008 with a 10 percent market penetration of new vehicle sales by 2020. For the fuel cell options, deployment is assumed to begin in 2012, will full penetration somewhat after 2030.

As a result of the market penetration assumption, the Group 1 fuel efficiency options with 100 percent market penetration result in significantly more petroleum displacement than the Group 2 fuel substitution options. Clearly, the differing market penetration assumptions preclude direct comparison of petroleum displacement and DNNB between the Group 1 and Group 2 options.

The Fischer-Tropsch diesel (FTD) option assumed that deployment would begin in 2008 with 2 percent conventional diesel displacement, increasing to 33 percent by 2019. The feedstock for the synthetic fuel is assumed to be remote sources of natural gas. The FTD use is controlled by assumptions on its world supply volumes and requirements to meet California specifications for diesel fuel. Nevertheless, it was assumed that by 2019, all California diesel fuel would be blended with FTD at 33 percent.

Biodiesel fuels are typically derived from soybean oils, rapeseed oil, animal fats or recycled cooking greases. Two biodiesel options were considered. The first option assumed a 2 percent blend (B2) as a lubricity additive beginning in 2008 and held constant thereafter. The second biodiesel case is a 20 percent blend (B20) beginning in 2008, displacing 2 percent of total conventional diesel. The B20 case ramped up to a 20 percent substitution level by 2015 and held constant thereafter. The larger biodiesel option was also influenced by assumptions on biodiesel supply volumes, but like FTD was assumed to be fully implemented in California diesel fuel either at 2 percent or 20 percent by 2015.

Two different flexible fuel vehicle (FFV) cases were evaluated in this analysis. For both cases, it was assumed that FFV non-petroleum fuel use would be equivalent to 10 percent of the state's light-duty vehicle population by 2020 and 30 percent by 2030. The E85 case is an 85 percent ethanol gasoline blend. The Low Cost FFV fuel case is a 40 percent by volume ethanol blend with gasoline that is different from CaRFG3.

For the ethanol blend option, it was assumed that reformulated gasoline would contain 5.7 percent by volume ethanol until 2007, increasing to 10 percent in 2008 and thereafter. All gasoline sold would adhere to this specification.

Figures 3-7 and 3-8 show cumulative DNNB as a function of petroleum displacement for the light-duty vehicle options considered. As can be seen, the only light-duty option with positive DNNB is the grid-connected advanced hybrid electric vehicle with 20-mile ZEV range. Among the remaining options, the low cost FFV fuel and fuel cell options have the next best DNNBs and result in relatively large petroleum displacements (up to 2 billion gal/yr in 2030). Liquefied

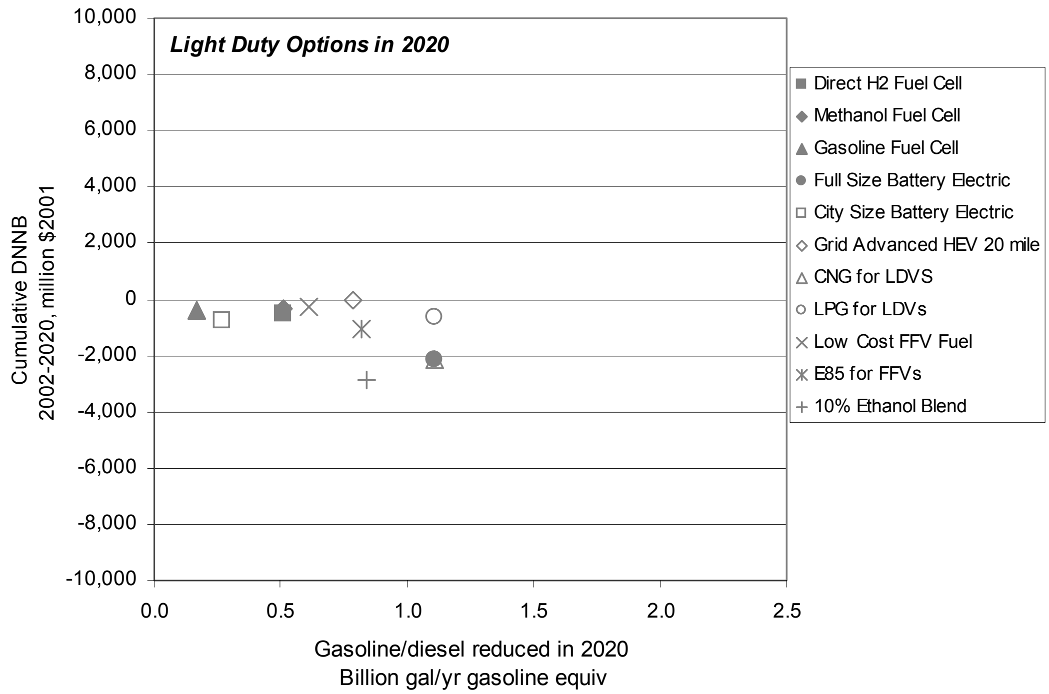


Figure 3-7. Cumulative DNNB as a Function of Petroleum Displacement in 2020 for the Group 2 Light-Duty Fuel Substitution Options

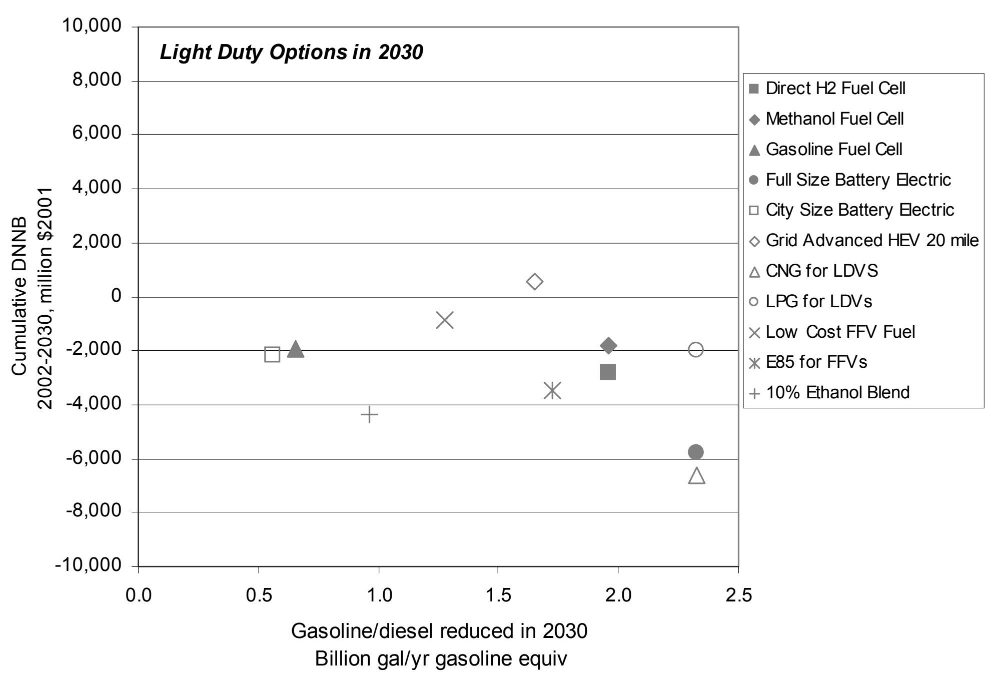


Figure 3-8. Cumulative DNNB vs. Petroleum Displacement in 2030 for the Group 2 Light-Duty Fuel Substitution Options

petroleum gas (LPG), full size battery electric and compressed natural gas (CNG) light-duty vehicle options have the highest petroleum displacement. The full size battery electric and CNG light-duty vehicle options, however, had the lowest DNNB.

Although the current analyses for options with increased ethanol use do not consistently result in positive DNB, the demand-side perspective employed to derive prices for fuels when blended with ethanol may underestimate the savings that can occur at the refinery. Possible supply side cost savings due to lower fuel production costs could be reflected in lower retail fuel prices. Furthermore, the analysis did not include benefits to the California economy from in-state ethanol production. By updating the analytic tools used to assess the economics of ethanol use at refineries and to verify the impact of alcohol fuels on vehicle emissions, the costs and benefits for the ethanol options could be more accurately estimated and used with greater confidence.

Although some light-duty fleets can economically use LPG and CNG and seem to contradict the present analysis, these fleets typically operate at much higher levels of VMT than what has been assumed here for private light-duty vehicles. Due to higher fuel throughput, these fleets may also secure lower unit fuel costs.

Figures 3-9 and 3-10 present the cumulative DNNB as a function of petroleum displacement for the medium- and heavy-duty options. The FTD option displaces the largest amount of petroleum (1.8 billion gal/yr in 2030) with a positive DNNB. The B20 option displaces the next greatest amount of petroleum, 1.1 billion gal/yr by 2030, but has a negative DNNB. The remaining medium- and heavy-duty options displace significantly lower levels of petroleum with slightly negative DNNB.

While the foregoing results are based on the assumption that the price of gasoline will remain at \$1.64 per gallon until 2030 and diesel will remain at \$1.65 per gallon, sensitivity analyses indicate that at higher fuel prices these options begin to produce more positive results. Figure 3-11 indicates the price of fuel required for a breakeven DNNB in 2030. For example, LNG for heavy-duty diesel vehicles and LPG for light-duty vehicles have breakeven points at \$1.79 per gallon diesel and \$1.89 per gallon gasoline, respectively. The direct hydrogen fuel cell option would require a breakeven point of \$2.19 per gallon gasoline and require technology advances, as well.

These results were obtained by determining the gasoline price needed for the alternative fuel option to break even on DNNB. The analyses did not account for any other possible changes in energy or technology costs and, therefore, is only approximate since higher conventional fuel prices will result in higher alternative fuel costs.

If petroleum based fuel prices rise such that the alternative fuel options compete economically, the actual market share could be greater than the 10 percent assumed here. Moreover, greater sales volumes can reduce technology costs due to economies of scale. However, near-term deployment requires public support, especially for establishing fuel infrastructure.

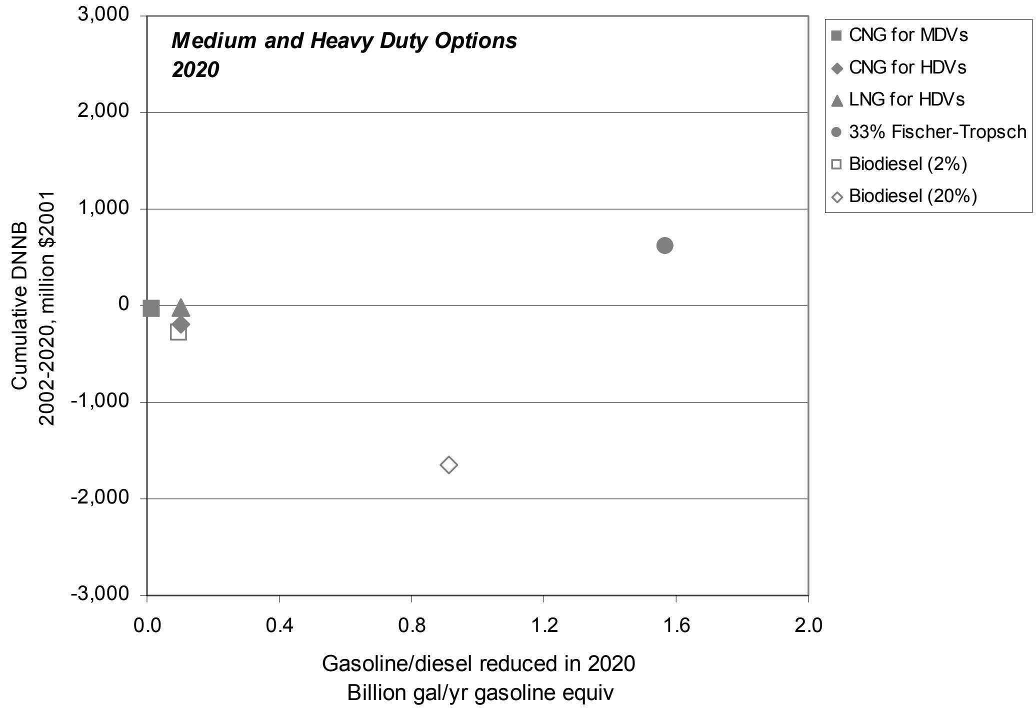


Figure 3-9. Cumulative DNNB vs. Petroleum Displacement in 2020 for the Group 2 Heavy-Duty Fuel Substitution Options

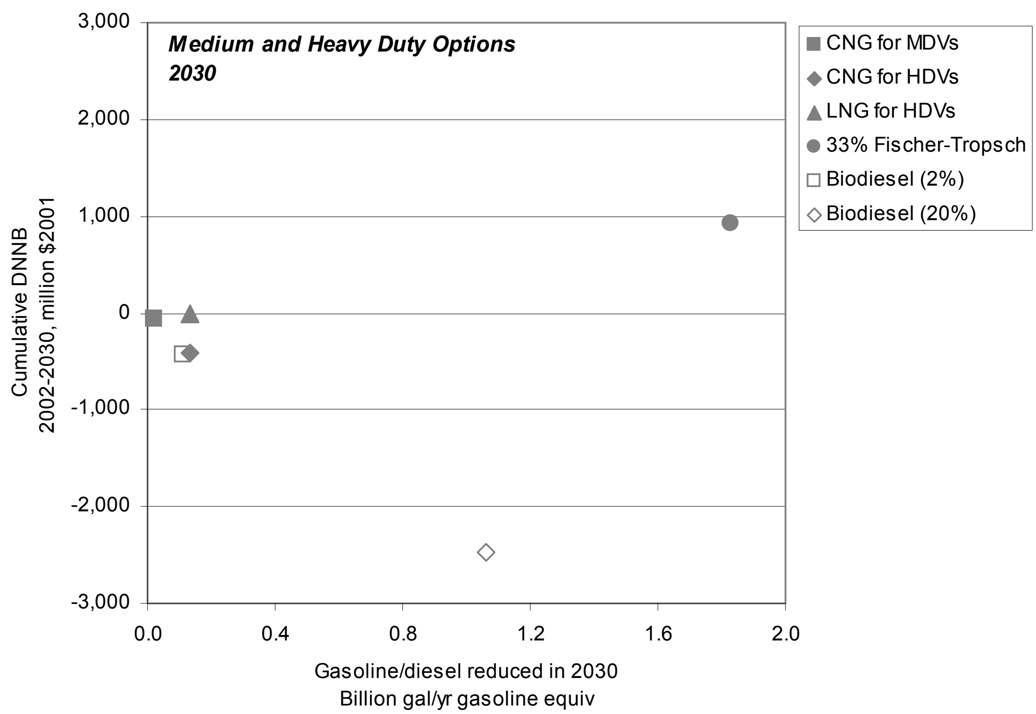


Figure 3-10. Cumulative DNNB vs. Petroleum Displacement in 2030 for the Group 2 Heavy-Duty Fuel Substitution Options

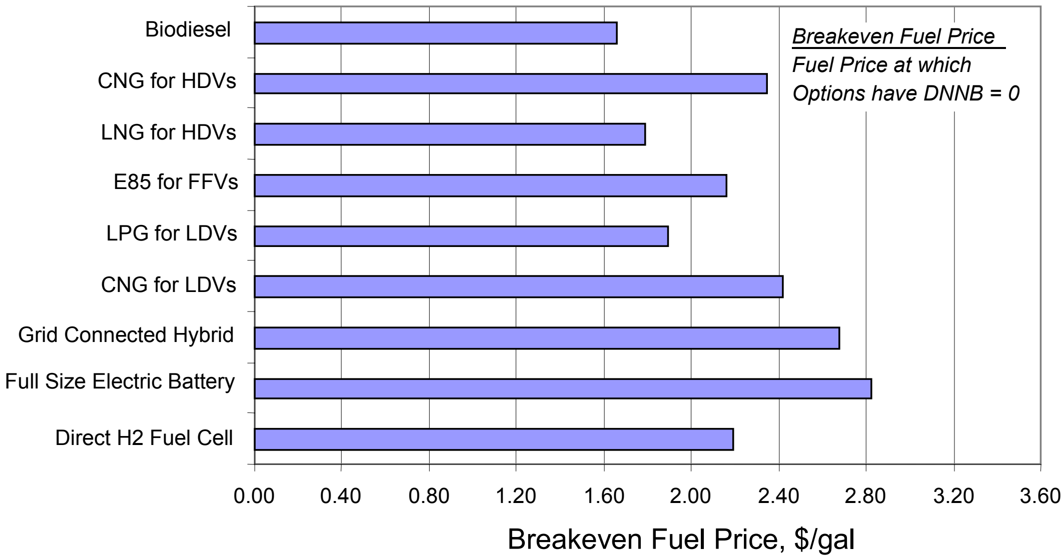


Figure 3-11. Gasoline/Diesel Fuel Prices at Which Options Have Zero DNNB

3.3 Summary — Key Findings of the Task 3 Analysis

Tables 3-2, 3-3 and 3-4 summarize the displacement and DNNB for each of the fuel efficiency, fuel substitution, and pricing options considered. As can be seen, even without consideration of environmental and external benefits, there are deployable petroleum fuel reduction options that result in overall positive DNNB. Options that can produce near term results include: the efficient replacement tires and tire inflation program, efficient government fleets, and an improved vehicle maintenance program.

In the 2010 to 2020 timeframe, significant reductions in consumption are possible through implementation of a variety of vehicle fuel economy options for light-duty gasoline vehicles and heavy-duty diesel vehicles. However, actions must be taken in the near-term to accrue these benefits in the 2010 to 2020 timeframe. Even if meaningful fuel economy options are implemented in the 2010 to 2020 timeframe, consumption will begin to increase again after 2020 (refer to Figure 3-5), due to projected increases in population and vehicle miles traveled.

Beyond 2020, the amount of uncertainty in the analysis increases. While it was assumed that fuel prices would be well behaved and average $1.64 per gallon throughout the analysis period, a variety of plausible conditions could produce higher fuel prices. If petroleum prices were to rise sufficiently, additional fuel substitution options would become economically competitive and could displace significant amounts of petroleum.

The key findings for the Group 1, Group 2 and Group 3 options are presented below. The Group 4 options are not presented in this report but results for these options may be found in the Task 1 and Task 3 reports.

Table 3-2. Summary of Displacement and DNNB for the Fuel Efficiency Options

Petroleum Reduction Option	Petroleum Displacement Billion gals in 2030 Gasoline eq.	Consumer Benefit 2002-2030 Billion $2001	Government Benefit 2002-2030 Billion $2001	DNNB 2002-2030 Billion $2001
Fuel Economy Improvements				
ACEEE Moderate, 29.9 mpg	6.28	26.74	-9.81	16.92
ACEEE Advanced, 34.4 mpg	8.04	32.10	-12.56	19.54
ACEEE Mild Hybrid, 39.9 mpg	9.71	7.89	-15.17	-7.28
ARB Mild Hybrid, 39.9 mpg	9.71	34.59	-15.17	19.42
ACEEE Full Hybrid, 45 mpg	10.86	-10.18	-16.96	-27.15
ARB Full Hybrid, 45 mpg	10.86	14.74	-16.96	-2.23
EEA, 27.7 mpg	5.03	24.75	-6.97	17.78
NRC Path 1, 23.3 mpg	2.34	7.93	-3.65	4.28
NRC Path 2, 28 mpg	5.30	9.57	-8.29	1.29
NRC Path 3, 31.4	6.90	1.68	-10.79	-9.10
Efficient Tires and Inflation	0.41	4.54	-1.50	3.04
Efficient Government Fleets	0.02	0.21	-0.04	0.17
Vehicle Maintenance Program	0.05	0.18	-0.31	-0.14
Efficient Medium-Duty Vehicles	0.07	0.29	-0.11	0.18
Efficient Heavy-Duty Vehicles	0.43	2.39	-0.66	1.73
Diesel Light-Duty Vehicles	0.40	1.03	-0.35	0.68

Table 3-3. Summary of Displacement and DNNB for the Fuel Substitution Options

Petroleum Reduction Option	Petroleum Displacement Billion gals in 2030 Gasoline eq.	Consumer Benefit 2002-2030 Billion $2001	Government Benefit 2002-2030 Billion $2001	DNNB 2002-2030 Billion $2001
Direct Hydrogen Fuel Cell	1.96	-1.20	-1.60	-2.80
Methanol Fuel Cell	1.96	-1.24	-0.59	-1.84
Gasoline Fuel Cell	0.65	-1.42	-0.53	-1.96
Full Size Electric Battery	2.33	-3.40	-2.40	-5.80
Grid Connected Hybrid	1.65	2.43	-1.85	0.58
CNG for Light-Duty Vehicles	2.33	-5.05	-1.54	-6.59
LPG for Light-Duty Vehicles	2.33	-1.93	-0.03	-1.96
Low Cost FFV Fuel (40% ethanol)	1.28	-0.04	-0.81	-0.84
E85 (85% ethanol) in FFVs	1.72	-0.13	-3.34	-3.47
10% Ethanol Blend	0.96	0.00	-4.38	-4.38
CNG for Heavy-Duty Vehicles	0.13	-0.25	-0.17	-0.41
LNG for HDVs	0.13	0.13	-0.15	-0.01
Fischer-Tropsch Diesel (33%)	1.83	0.93	0.00	0.93
Biodiesel (2%)	0.11	-0.43	0.00	-0.43
Biodiesel (20%)	1.06	-2.76	0.29	-2.48

Table 3-4. Summary of Displacement and DNNB for the Pricing Options

Petroleum Reduction Option	Petroleum Displacement Billion gals in 2030 Gasoline eq.	Consumer Benefit 2002-2030 Billion $2001	Government Benefit 2002-2030 Billion $2001	DNNB 2002-2030 Billion $2001
Gasoline Tax	1.05	-98.48	93.32	-5.15
Pay-at-the-Pump Insurance	0.88	1.35	-2.58	-1.23
Pay-as-you-Drive Insurance	0.59	1.35	-1.77	-0.43
Vehicle Miles Traveled Tax	0.63	-84.30	80.92	-3.38
State Feebate	1.43	8.57	-2.49	6.08
Nationwide Feebate	4.26	34.15	-7.25	26.90
Registration Fee Transfer	0.17	0.05	-0.51	-0.46
Incentives for Efficient Vehicles	0.13	16.96	-18.10	-1.14

Group 1 (Fuel Efficiency Options)

The fuel efficiency options have the potential to displace the most petroleum with positive DNNB at gasoline and diesel prices of $1.64 per gallon.

- For the assumptions and scenarios considered in Task 3, the use of vehicle and engine technologies to improve vehicle fuel economy provided the largest gasoline reduction of all of the options evaluated while also producing positive consumer and direct non-environmental net benefits when compared to the base case gasoline demand forecast. The estimated reductions in 2030 range from about 9 to 45 percent of the base case forecast.

- Use of fuel-efficient (i.e., low rolling resistance) tires and proper tire inflation, the purchase of commercially available efficient vehicles by government fleets, and improved vehicle maintenance practices, are attractive near-term options (i.e., less than five years to implement). Although the petroleum displacement is relatively small, 0.1 to 2 percent of the base case forecast, the net benefit is positive and implementation sets a positive leadership example.

- Medium- and heavy-duty diesel efficiency improvements result in positive net benefits but relatively small reductions in petroleum fuel consumption compared to the base case.

Group 2 (Fuel Substitution Options)

While alternative fuels can achieve large reductions in petroleum fuel demand if economies of scale are achieved and convenient fueling infrastructure is established, these options, with a few exceptions, do not currently compete well with petroleum fuels. If petroleum fuels become more expensive, additional alternative fuel options become economically competitive. Wide scale near-term deployment requires public support, especially for fuel infrastructure establishment. Conversely, blending Fischer-Tropsch diesel with California diesel has a positive DNNB.

- FTD blending provides positive DNNB and could be used as a near-term option to reduce petroleum dependency.

- The direct hydrogen fuel cell vehicle is a long-term option that approaches the cost-effectiveness threshold (zero DNNB). This technology offers efficiency improvements if technology and fuel costs and performance targets are achieved.

Group 3 (Pricing Options)

Historically, the use of pricing mechanisms to influence consumer behavior has required considerable political and consumer consensus. While the analysis in certain cases projects significant petroleum displacement and net benefits, there is no expectation that such a consensus can be achieved to debate or implement these mechanisms. For completeness, results are presented but these options are judged to be politically impractical.

- Nationwide and state feebates provide direct nonenvironmental net benefits (DNNB).

4. Benefits of Reducing Petroleum Demand

This section of the report summarizes the DENB and the ECPD. The environmental benefits include improved air quality, reduced GHG emissions, and fewer accidental petroleum spills. For each of the options considered, the environmental impacts were determined and converted to economic terms. The external costs account for the impact of petroleum prices and fluctuations of the prices on the economy. The methodology adopted for this analysis is summarized in Section 2 of this report.

This section presents key results for the Group 1 fuel efficiency and Group 2 fuel substitution options only. The integrated results for the pricing options are presented in Section 5 of this report. The other options are not included because environmental results were not quantified. For a detailed description of all the petroleum reduction options, please refer to the report entitled Appendix A: Reducing Demand for Gasoline and Diesel (Task 1).

4.1 Magnitude of Environmental Impacts

In quantifying the environmental benefits attributed to each of the petroleum reduction options, the emissions from the entire fuel cycle (wells to wheels) were considered. Criteria and toxic air pollutant emission changes and multimedia impacts that take place out-of-state were excluded from this analysis even though they may have resulted from reduced fuel consumption in California. Alternatively, because global GHG emissions impact California, all changes in fuel cycle GHG emissions are considered, even if they occur outside of California. The following sections present the air quality, GHG and multimedia impacts for each of the petroleum reduction options evaluated.

4.1.1 Air Quality Improvements

Reductions in petroleum dependency can reduce not only the on-road contribution to air pollution but also the upstream fuel cycle contribution including petroleum extraction, transportation, storage, distribution and marketing. The air pollutants considered in this evaluation consist of NO_x, selected criteria air pollutants — NMOG, CO, PM, and selected toxic air contaminants — 1,3-butadiene, acetaldehyde, benzene, formaldehyde. The impact of ozone, formed from the atmospheric interaction between NO_x and NMOG is also evaluated.

As explained in Section 1.1.5 of this report, many areas of our state do not attain the state and federal standards for ambient concentrations of ozone, CO and PM. In 2002, on-road sources were responsible for 40 percent of the statewide emissions of NO_x, CO and NMOG. Likewise, in 1996, on-road sources were responsible for more than half of the statewide emissions of the four air toxic compounds evaluated in this study.

Air quality emission impacts result from fuel cycle and/or vehicle emission changes. For the Group 1 fuel efficiency options, it was assumed that VMT is unchanged compared to the base case. As a result, there is no change in vehicle emissions since emission standards are measured on a gram per mile basis. These fuel efficiency options derive criteria and toxic emission reductions only through upstream fuel cycle emission reductions. In contrast, many of the Group 2 fuel substitution options provide both fuel cycle and tailpipe emission reductions.

Figure 4-1 presents the predicted emission reductions for the Group 1 fuel efficiency options. Figure 4-2 presents the emission reductions for the light-duty Group 2 fuel substitution options. The air quality benefits for the fuel economy options are proportional to their nominal fuel economy level. The best Group 2 options are full size electric battery, fuel cells, and grid connected hybrids. These options provide roughly three times the air quality benefit of the best fuel efficiency options even though the best fuel efficiency options result in an order of magnitude more petroleum reduction. This is because fuel economy improvements do not change the grams of pollutants emitted per mile driven.

The heavy-duty Group 2 Fuel Substitution emission impacts are presented in Figure 4-3. As can be seen, most of these options provide very little change in criteria and air toxic emissions. The 20 percent biodiesel blend option yields the largest increase in upstream fuel cycle emissions of all the pollutants evaluated.

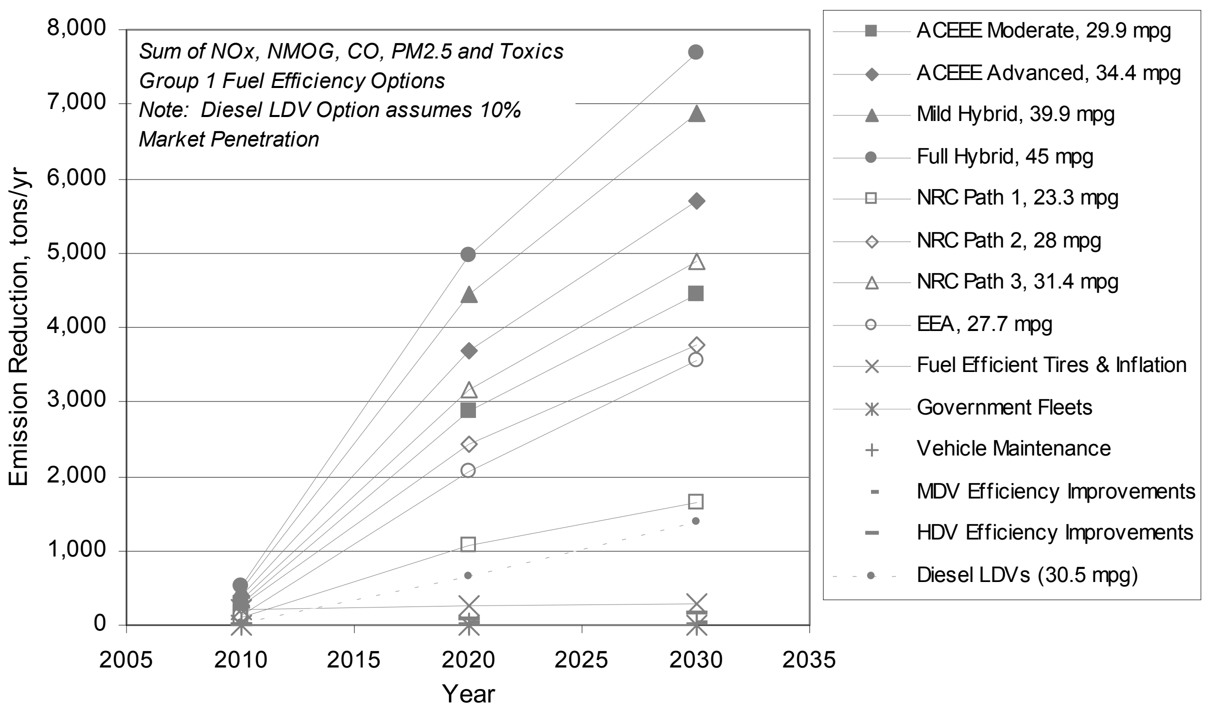


Figure 4-1. Criteria and Air Toxic Pollutant Emission Reductions for the Group 1 Fuel Efficiency Options and Scenarios

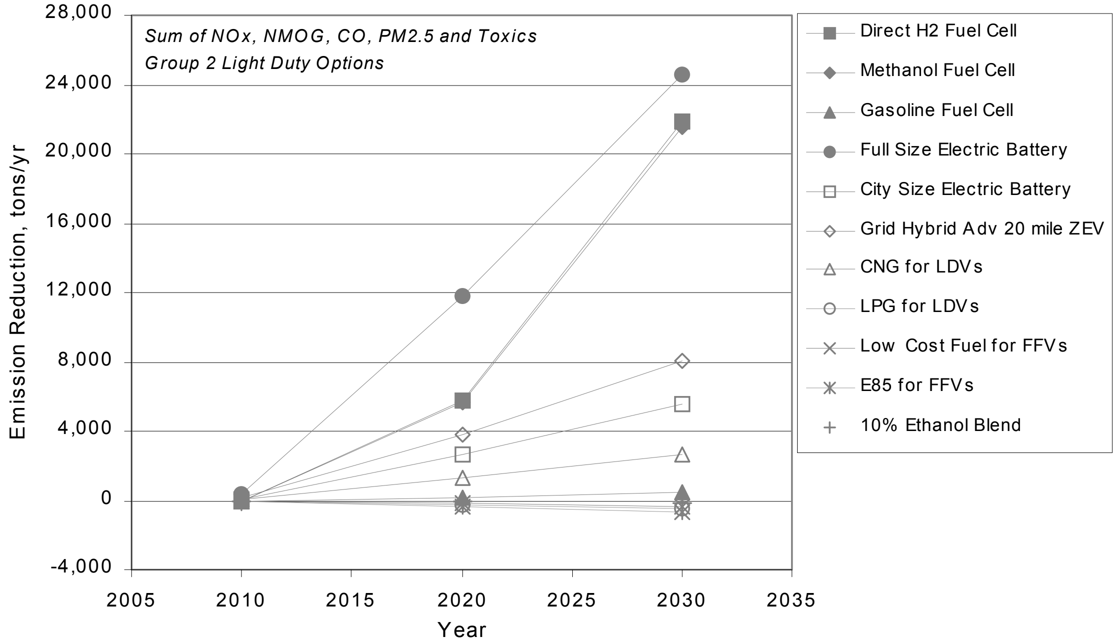


Figure 4-2. Criteria and Air Toxic Pollutant Emission Reductions for the Light-Duty Group 2 Fuel Substitution Options

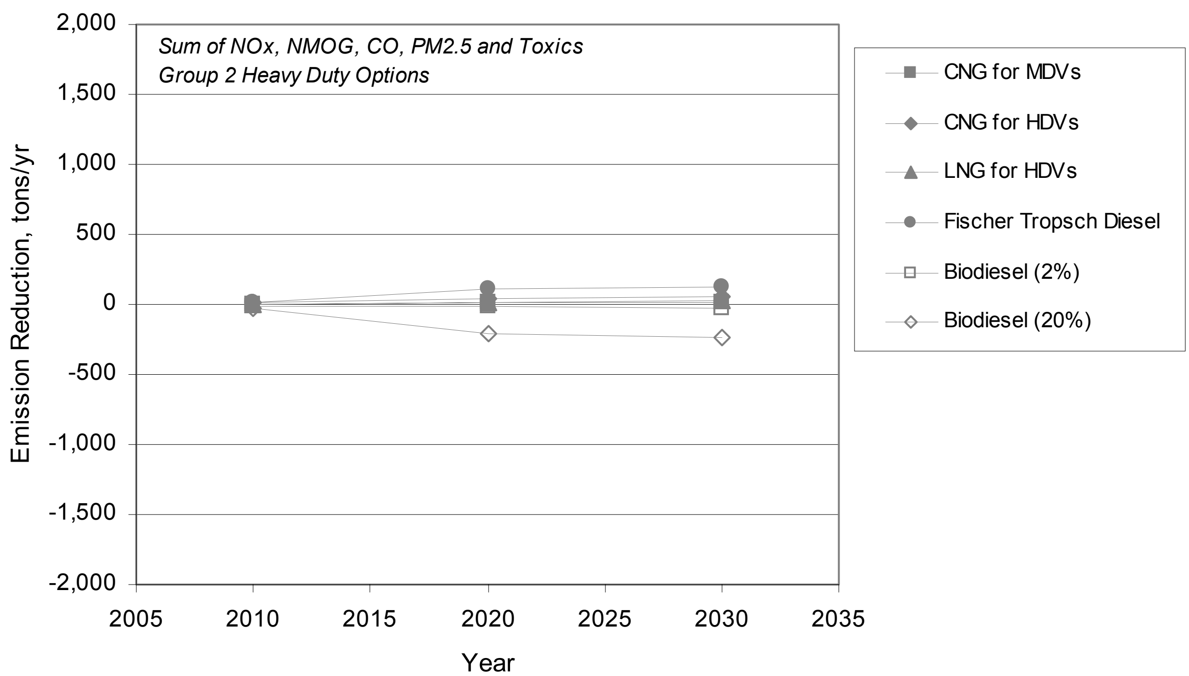


Figure 4-3. Criteria and Air Toxic Pollutant Emission Reductions for the Medium- and Heavy-Duty Group 2 Fuel Substitution Options

4.1.2 Greenhouse Gas Emission Reductions

Since on-road mobile source emissions of CO_2, CH_4, and N_2O equal half of the state's total GHG emissions, changes in on-road consumption of petroleum based fuels can significantly affect the state's emissions of GHGs. Because the amount of carbon dioxide that is formed in the combustion process is directly proportional to the amount of carbon in the fuel that is burned, GHG emissions can be reduced either by improved fuel economy or by displacing petroleum fuels with lower carbon content fuels. Because both of these strategies reduce petroleum based fuel consumption, both result in reduced upstream fuel cycle emissions of GHGs as well.

Figures 4-4 through 4-6 present the GHG emission reductions for the Group 1 fuel efficiency options, light-duty Group 2 fuel substitution options, and heavy-duty Group 2 fuel substitution options, respectively. The best Group 1 fuel efficiency option reduces annual GHG emissions by over 130 million tons in 2030, equivalent to about 30 percent of California's total GHG emissions in 1999.

Because the Group 1 and Group 2 market penetration assumptions are much different, the Group 2 GHG emission reductions can not be directly compared to the Group 1 reductions. However, had the market penetration results for Group 1 and Group 2 been the same, the best displacement option would have had a larger GHG emission impact than the best fuel economy option since displacement options include both technology and fuel GHG reductions.

The light-duty diesel option, which is a fuel efficiency option, was evaluated using the same market penetration assumption as the Group 2 fuel substitution options. With an assumed limit of new vehicle sales equal to 10 percent of the annual market volume, this option provides 6.3 million tons of annual GHG reduction by 2030.

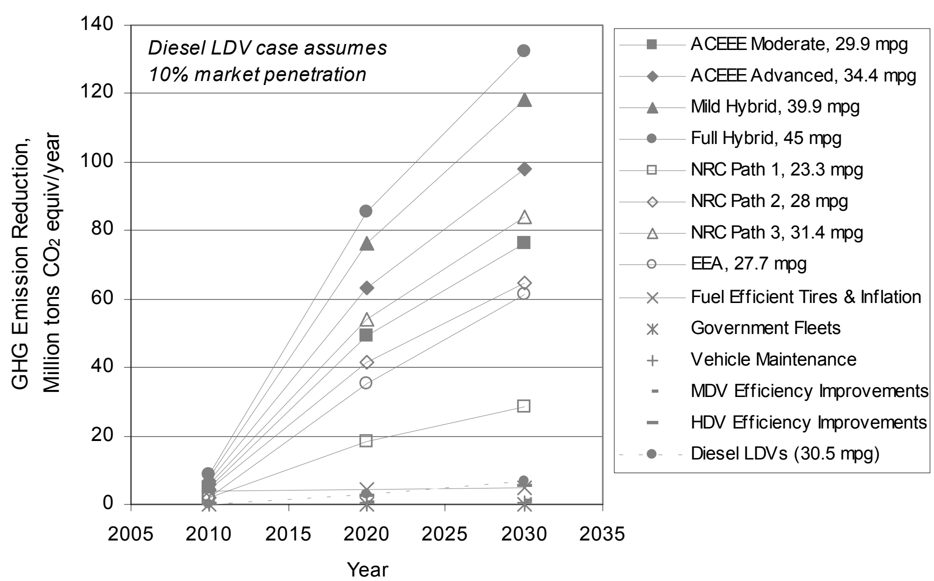


Figure 4-4. Greenhouse Gas Emission Reductions for the Group 1 Fuel Efficiency Options and Scenarios

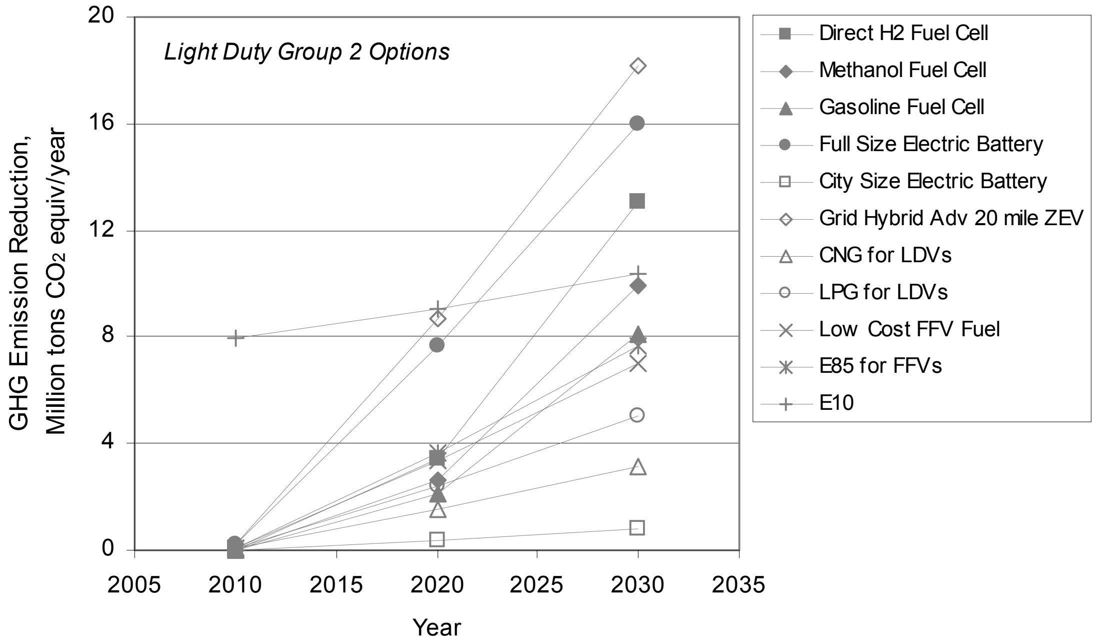


Figure 4-5. Greenhouse Gas Emission Reductions for the Light-Duty Group 2 Substitution Options

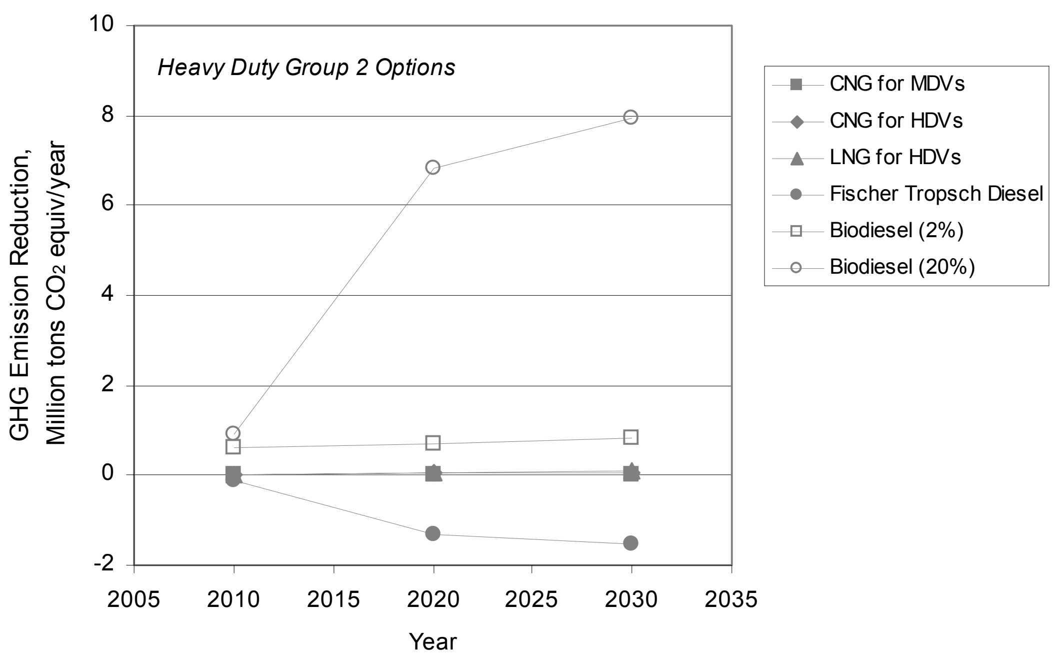


Figure 4-6. Greenhouse Gas Emission Reductions for the Medium and Heavy-Duty Group 2 Substitution Options

The E10 option, in which 10 percent ethanol is blended into all gasoline sold, provides the largest GHG reduction in the near term of all the Group 2 options. However, this improvement levels off over time, and compared to the fuel economy options, the GHG reductions are small.

The B20 option, in which 20 percent biofuels are blended with all diesel fuel sold, yields the largest GHG reduction of the heavy-duty options. However, compared to the light-duty fuel efficiency options, the reductions are relatively small. Also noteworthy is the increase in GHG emissions for the FTD option. This increase results from the higher amounts of energy required to convert natural gas to the synthetic liquid diesel fuel than to convert petroleum to diesel.

4.2 Valuation of Benefits

A benefit transfer analysis was performed for each air pollutant or gallon of petroleum displaced in which the benefits of avoided damages are quantified on the basis of avoided damage cost per ton of pollutant ($/ton pollutant) or avoided damage cost per gallon of petroleum reduced ($/gallon reduced). The monetary values associated with reducing emissions and petroleum throughput are described in detail in the Task 1 report attached as Appendix A[13], and briefly summarized in Section 2 of this report. The $/ton-pollutant or $/gallon-reduced are multiplied by the tons avoided or the gallons avoided to monetize the benefits of various petroleum reduction options. The DENB was then estimated by summing the present value of annual estimated benefits over the periods of interest. A discount rate of 5 percent was utilized.

The range of damage values, $/ton-pollutant or $/gallon-reduced, varies from a fraction of a cent per gallon to over $300,000 per ton. However, these values must be combined with the direct emission or fuel reductions projected for each option before a true benefit can be determined. Table 4-1 provides the avoided costs estimates for each major damage category and for each type of pollutant in those categories.

The estimates of damage values were primarily taken from Delucchi[14] and the results of Friedrich and Bickel[15] for Europe. Mid-range point values from these studies were used in this analysis. $PM_{2.5}$ damages were determined using a methodology that estimated direct emissions, changes in exposure levels, and associated changes in human mortality and morbidity. These changes where then valued using a willingness to pay approach that values the avoided change in human health. The U.S. EPA and ARB have used this procedure in several regulatory impact analyses.

[13] Ibid.

[14] Delucchi, Mark A, *Summary of the Nonmonetary Externalities of Motor-Vehicle Use*, Report #9 in the series: The Annual Social Cost of Motor-Vehicle Use in the U.S., based on 1990-1991 Data, UCD-ITS-RR-96-3 (9), September 1998.

[15] Friedrich, Rainer and Peter Bickel, Editors, *Environmental External Costs of Transport*, ISBN 3-540-42223-4, Springer, 2001.

Table 4-1. Value of Avoided Damages for Each Pollutant

Damages	Pollutant	Damage Value 2001$/Unit	Normalizing Unit
Human Health	CO	220	Ton
	NO_x including secondary particulate	88,000	Ton
	$PM_{2.5}$ (direct)	331,000	Ton
	VOC	5,000	Ton
	VOC+NO_x (ozone)	460	Ton
Visibility	PM_{10}	3,400	Ton
	NO_x	1,000	Ton
	VOCs	47	Ton
Water Pollution[a]	Oil, gasoline, diesel	0.009	Gallon diesel or gasoline
Agriculture	VOC+NO_x (ozone)[b]	300	Ton
Materials	VOC+NO_x (ozone)[b]	400	Ton
Forests	VOC+NO_x (ozone)[b]	110	Ton
Global Warming—human health, terrestrial, aquatic ecosystem	CO_2, N_2O equiv CO_2, CH_4 equiv CO_2	15	Ton

[a] Leaking underground tanks (UGT), oil spills, urban runoff.
[b] Only VOC+NO_x as a surrogate for ozone was considered for these damages.

Global warming damages were estimated from several studies that itemized the damages throughout the world caused by increasing surface temperatures, more extreme weather conditions, and increasing sea levels. Monetized damages were normalized by GHG emissions. The resulting $damage/ton-$CO_2$ equivalent was confirmed by comparison to several other studies.

Toxic air contaminates were not monetized since there was no accepted methodology on evaluating the health based damages associated with each TAC. Relative cancer risks could have been used, but here again there is no acceptable monetized value for cancer risks. More work will be needed to monetize TAC health damage effects.

Group 1 Options. All of the Group 1 fuel efficiency options have a positive DENB and all of the components of the DENB are positive. As shown in Figure 4-7, DENB for the Group 1 options is proportional to the nominal fuel economy level. When the key elements of the environmental benefits are separately displayed as in Figure 4-8, it is clear that the total environmental benefit is dominated by reductions in GHG emissions. The contributions from reduced spills of fuels and air quality benefits are about equal in magnitude.

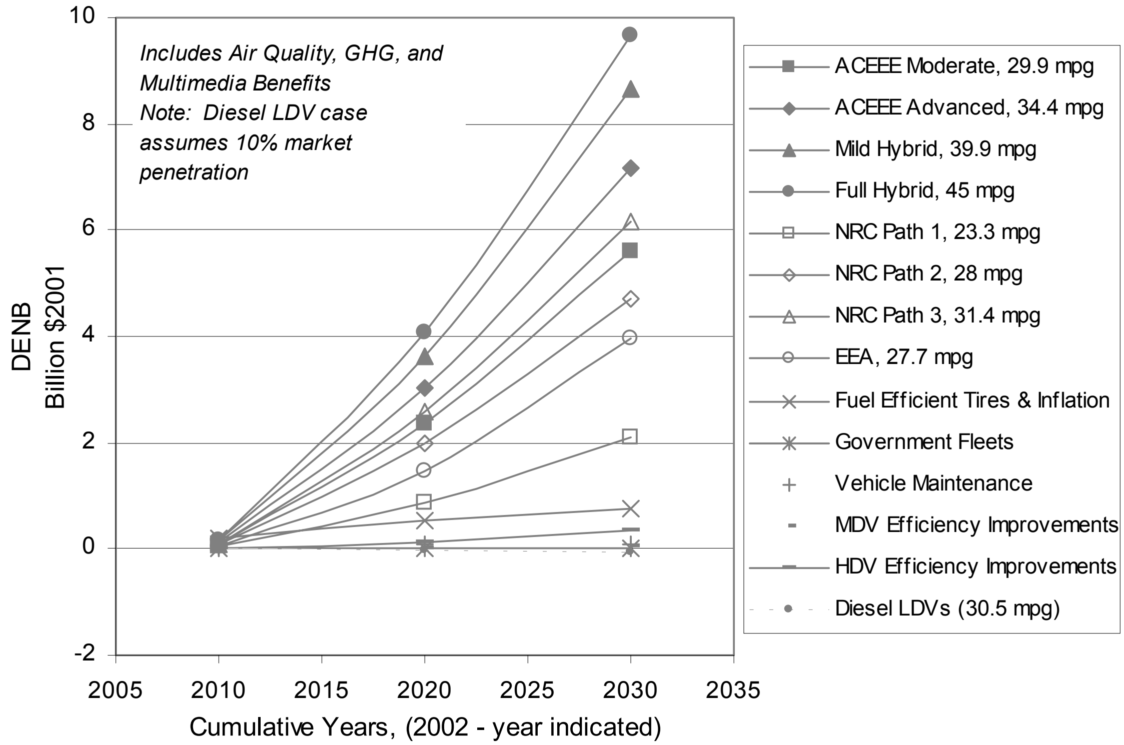


Figure 4-7. Cumulative DENB for the Group 1 Fuel Efficiency Options and Scenarios

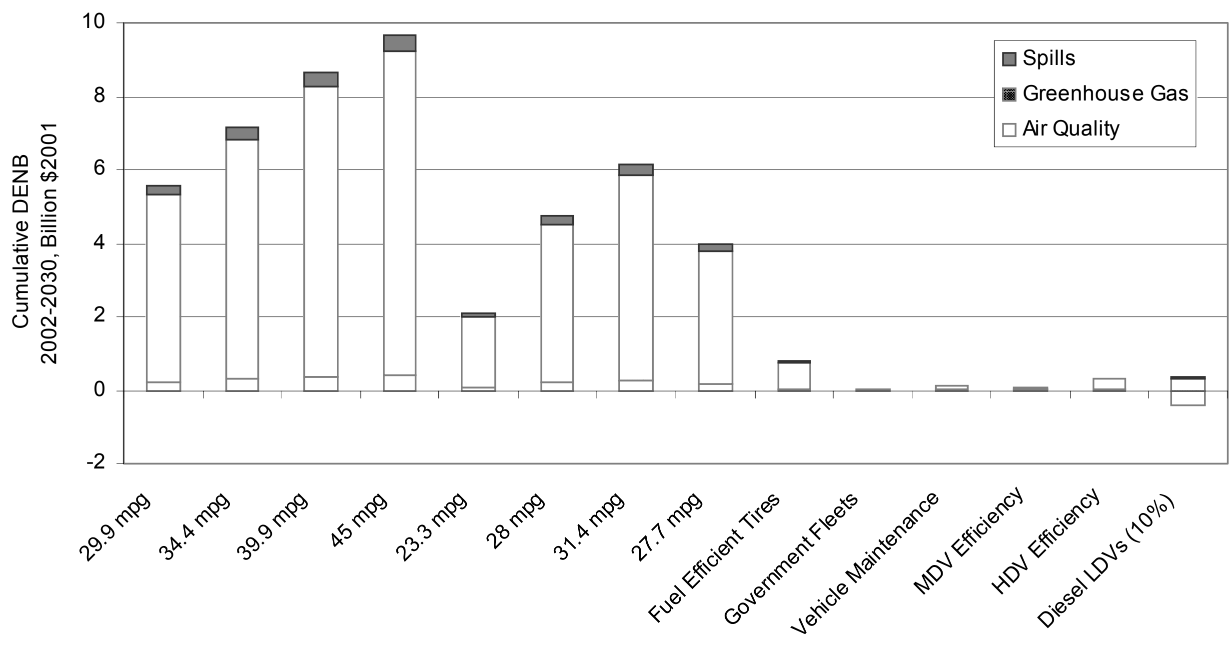


Figure 4-8. Breakdown of DENB for the Group 1 Fuel Efficiency Options and Scenarios

Group 2 Options. Among the light-duty Group 2 fuel substitution options shown in Figure 4-9, the 10 percent ethanol blend, full size electric battery vehicles, and grid connected hybrids have the highest DENB. These options have the highest DENB because they displace the most petroleum. Also, the full size electric battery vehicle and grid connected hybrid have large air quality benefits.

Among the heavy-duty Group 2 options shown in Figure 4-10, the 20 percent biodiesel blend provides the largest DENB because it displaces the most diesel fuel. As a result, the GHG component of DENB is quite large and outweighs the negative air quality component. The DENB for the 20 percent biodiesel option is comparable to the average Group 2 light-duty DENB result. Also notable is the negative DENB for the FTD option. This is due to the increase in fuel cycle GHG emissions.

As can be seen in Figure 4-11, the largest component of the Group 2 DENB is the GHG reduction. However, the air quality component of the DENB is a larger percentage of the total than for the Group 1 options and is substantial. This is because the Group 2 options result in both fuel cycle and vehicle emission reductions while the fuel economy options only provide fuel cycle criteria pollutant reductions.

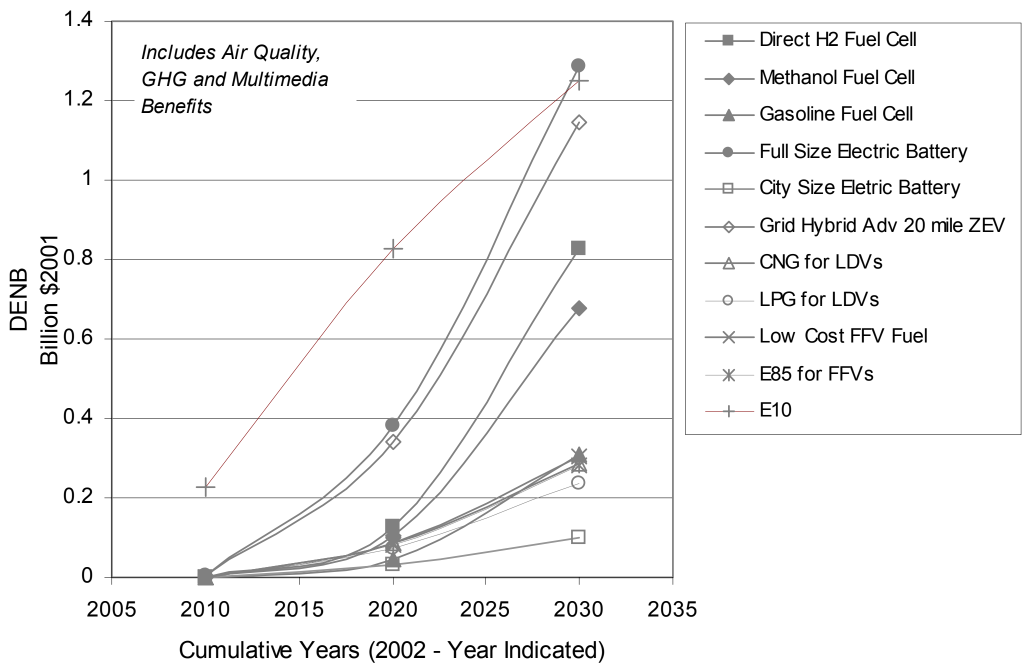


Figure 4-9. Cumulative DENB for the Light-Duty Group 2 Fuel Substitution Options

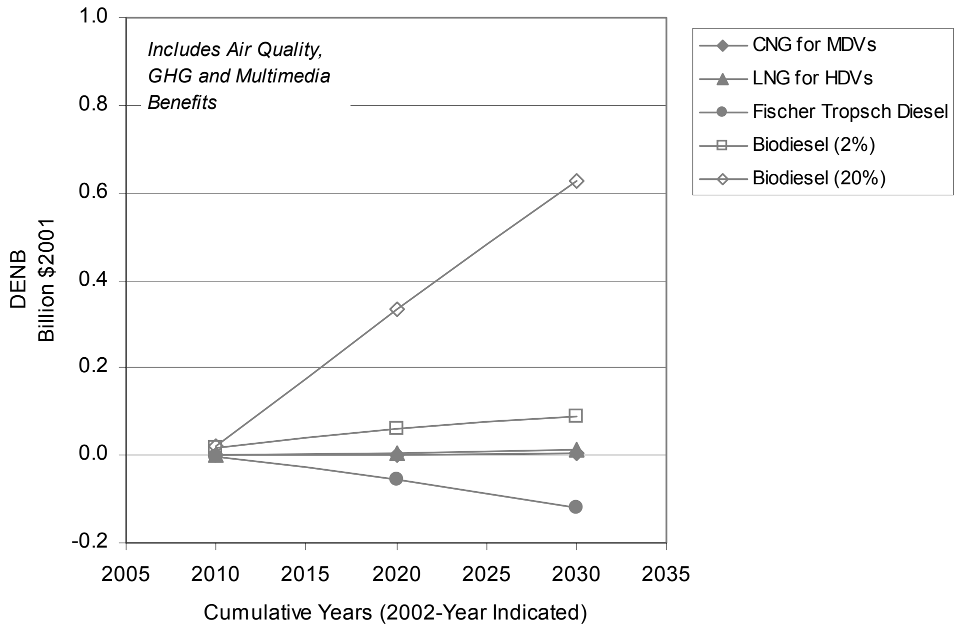


Figure 4-10. Cumulative DENB for the Medium and Heavy-Duty Group 2 Fuel Substitution Options

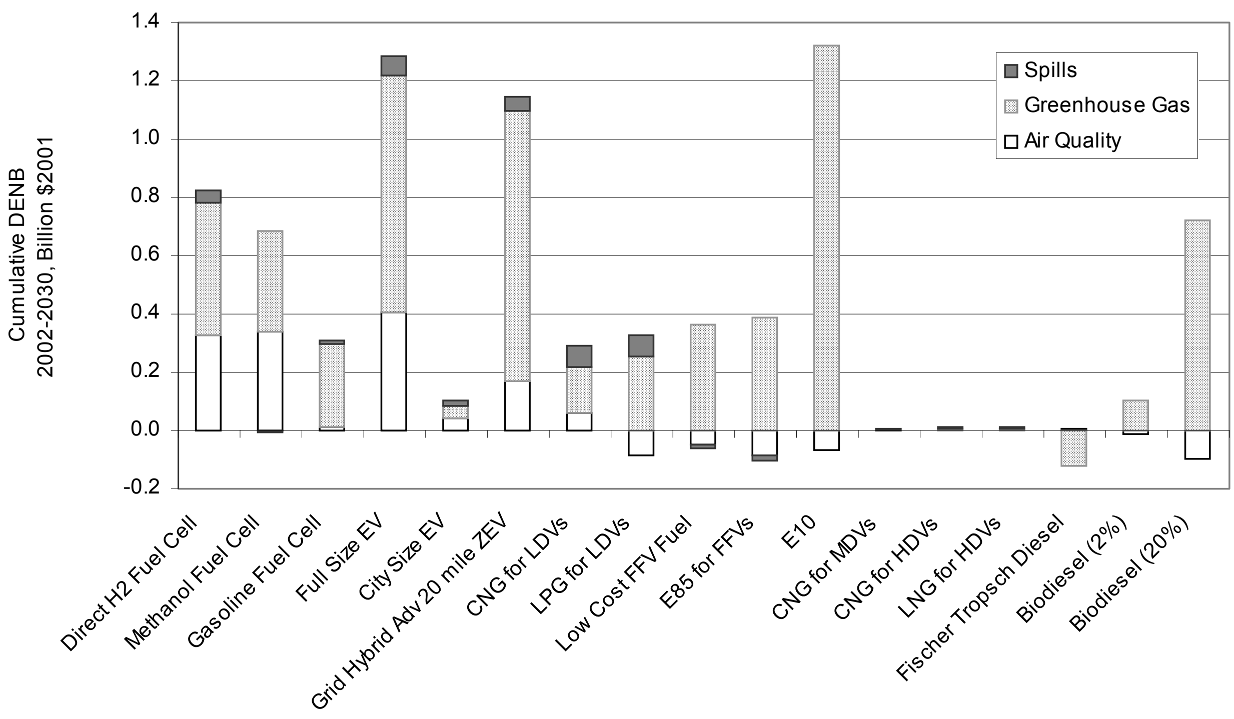


Figure 4-11. Breakdown of DENB for the Group 2 Fuel Substitution Options

External Cost of Petroleum Dependency. The benefit resulting from a reduction in the external cost of petroleum dependency is based upon a damage value estimated to be $0.12 per gallon reduced. Damages to the U.S. economy due to petroleum dependency were determined from a review of literature estimates. Estimates of these external costs ranged from negligible to $0.30 per gallon of gasoline. For this analysis we choose a middle price that seems consistent with the recent NRC-NAS[16] report on vehicle fuel economy.

The overall benefit value for the external cost of petroleum dependency is directly proportional to the displacement of petroleum fuel. Thus, as displayed in Table 4-2, the largest benefit among the Group 1 options is the highest light-duty vehicle fuel economy case. Among the Group 2 options, the FTD option produced the largest external cost benefit (see Table 4-3).

Table 4-2. Benefits From Using Fuel Efficiency Options and Scenarios to Reduce the External Cost of Petroleum Dependence

	Billion $2001		
	2002-2010	**2002-2020**	**2002-2030**
ACEEE Moderate, 29.9 mpg	0.05	1.41	3.35
ACEEE Advanced, 34.4 mpg	0.07	1.81	4.30
Mild Hybrid, 39.9 mpg	0.09	2.19	5.19
Full Hybrid, 45 mpg	0.10	2.45	5.80
NRC Path 1, 25.3 mpg	0.02	0.53	1.25
NRC Path 2, 28.8 mpg	0.05	1.19	2.84
NRC Path 3, 34.4 mpg	0.06	1.55	3.69
EEA, 27.7 mpg	0.02	0.88	2.38
Fuel Efficient Tires & Inflation	0.13	0.33	0.47
Government Fleets	0.00	0.01	0.01
Vehicle Maintenance	0.02	0.04	0.06
Light Duty Diesel, 30.5 mpg	0.00	0.09	0.29
MDV Efficiency Improvements	0.00	0.01	0.03
HDV Efficiency Improvements	0.00	0.07	0.18

[16] *Effectiveness and Impact of Corporate Average Fuel Economy (CAFÉ) Standards*, National Academy of Sciences, 2002.

Table 4-3. Benefits From Using Fuel Substitution Options to Reduce the External Cost of Petroleum Dependence

	Billion $2001		
	2002-2010	2002-2020	2002-2030
Direct Hydrogen Fuel Cell	0.00	0.08	0.55
Methanol Fuel Cell	0.00	0.08	0.55
Gasoline Fuel Cell	0.00	0.03	0.18
Full Size Electric Battery	0.00	0.28	0.94
City Size Electric Battery	0.00	0.07	0.23
Grid Hybrid Adv 20 mile ZEV	0.00	0.20	0.67
CNG for LDVs	0.00	0.28	0.94
LPG for LDVs	0.00	0.28	0.94
Low Cost FFV Fuel	0.00	0.15	0.50
E85 in FFVs	0.00	0.21	0.70
E10	0.18	0.65	0.98
CNG for MDVs	0.00	0.01	0.01
CNG for HDVs	0.00	0.03	0.08
LNG for HDVs	0.00	0.03	0.08
Fischer Tropsch Diesel	0.02	0.48	1.03
Biodiesel (2%)	0.02	0.06	0.10
Biodiesel (20%)	0.02	0.37	0.69

Table 4-4. Benefits From Using Pricing Options to Reduce the External Cost of Petroleum Dependence

	Billion $2001		
	2002-2010	2002-2020	2002-2030
Gasoline Tax ($0.50)	0.48	0.97	1.33
Pay-at-the-Pump Insurance	0.39	0.79	1.09
Pay-as-you-Drive Insurance	0.32	0.61	0.81
Tax on Vehicle Miles	0.34	0.65	0.86
California Feebate	0.13	0.55	1.01
Nationwide Feebate	0.32	1.48	2.83
Registration Fee Transfer	0.08	0.16	0.22
Efficient Vehicle Incentives	0.02	0.07	0.11

4.3 Summary — Key Findings of the Task 1 Analysis

Tables 4-5 and 4-6 summarize the environmental benefits and external costs of petroleum dependency. The environmental benefits include NO_x criteria pollutants NMOG, CO, and PM, and greenhouse gases (CO_2, CH_4 and N_2O), and water pollution. These components are then summed to provide DENB. It is important to note that the health based benefits of reducing toxic air contaminates were not included in this assessment due to the lack of an acceptable methodology. Also shown are the impacts on the external cost of petroleum dependence (ECPD). As used here positive results indicate benefits for both DENB and ECPD.

In general these results indicate that reducing petroleum use results in environmental and external dependency benefits. All of the options provide positive ECPD results. Key results for the Group 1, Group 2 and Group 3 options are presented below.

Group 1 (Fuel Efficiency Options)

The improved light-duty fuel economy options yield large reductions in petroleum fuel use and therefore result in large ECPD and GHG benefits. None of the Group 1 options results in negative benefits (costs) for any of the categories considered. Key points include:

- DENB for the fuel economy cases is proportional to the nominal average fuel economy level.
- Improved fuel economy yields the largest GHG benefit since these options are fully implemented into the vehicle fleet and provide the largest reductions in petroleum use. The best fuel economy case reduces annual GHG emissions in 2030 by an amount equal to 30 percent of the state's 1999 GHG inventory.
- The fuel economy options result in relatively low air quality benefit. This is because vehicle tailpipe emissions are regulated in units of grams per mile and vehicle efficiency options do not change vehicle emissions on a per mile basis. In general, air quality benefits for the fuel efficiency options result from reductions in upstream fuel cycle emissions.
- Water pollution benefits are proportional to the amount of petroleum fuel displaced and are of the same magnitude as the air quality benefits.
- DENB is dominated by the greenhouse gas component for the Group 1 options.
- The ECPD benefits are similar in magnitude to the GHG benefits for these options.

Table 4-5. Components of DENB and ECPD for the Group 1 Options and Scenarios

Petroleum Reduction Option	Cumulative Benefits				
	Air Quality 2002-2030 Billion $2001	GHG 2002-2030 Billion $2001	Water Pollution 2002-2030 Billion $2001	DENB 2002-2030 Billion $2001	ECPD 2002-2030 Billion $2001
Fuel Economy Improvements					
ACEEE Moderate, 29.9 mpg	0.24	5.10	0.25	5.59	3.35
ACEEE Advanced, 34.4 mpg	0.30	6.54	0.32	7.16	4.30
ACEEE Mild Hybrid, 39.9 mpg	0.36	7.90	0.39	8.65	5.19
ARB Mild Hybrid, 39.9 mpg	0.36	7.90	0.39	8.65	5.19
ACEEE Full Hybrid, 45 mpg	0.41	8.83	0.44	9.68	5.80
ARB Full Hybrid, 45 mpg	0.41	8.83	0.44	9.68	5.80
EEA, 27.7 mpg	0.17	3.63	0.18	3.97	2.38
NRC Path 1, 23.3 mpg	0.09	1.90	0.09	2.08	1.25
NRC Path 2, 28 mpg	0.20	4.31	0.21	4.73	2.84
NRC Path 3, 31.4	0.26	5.62	0.28	6.15	3.69
Efficient Tires and Inflation	0.03	0.71	0.03	0.78	0.47
Efficient Government Fleets	0.00	0.02	0.00	0.02	0.01
Vehicle Maintenance Program	0.00	0.10	0.00	0.10	0.06
Efficient Medium-Duty Vehicles	0.00	0.05	0.00	0.06	0.03
Efficient Heavy-Duty Vehicles	0.01	0.31	0.01	0.33	0.18
Diesel Light-Duty Vehicles	-0.42	0.33	0.02	-0.07	0.29

Table 4-6. Components of DENB and ECPD for the Group 2 Options

Petroleum Reduction Option	Cumulative Benefits				
	Air Quality 2002-2030 Billion $2001	GHG 2002-2030 Billion $2001	Water Pollution 2002-2030 Billion $2001	DENB 2002-2030 Billion $2001	ECPD 2002-2030 Billion $2001
Direct Hydrogen Fuel Cell	0.33	0.46	0.04	0.83	0.55
Methanol Fuel Cell	0.34	0.35	-0.01	0.68	0.55
Gasoline Fuel Cell	0.01	0.28	0.01	0.31	0.18
Full Size Electric Battery	0.41	0.81	0.07	1.29	0.94
Grid Connected Hybrid	0.17	0.92	0.05	1.14	0.67
CNG for Light-Duty Vehicles	0.06	0.16	0.07	0.29	0.94
LPG for Light-Duty Vehicles	-0.09	0.25	0.07	0.24	0.94
Low Cost FFV Fuel	-0.05	0.37	-0.01	0.31	0.50
E85 (85% ethanol) in FFVs	-0.08	0.39	-0.02	0.28	0.70
10% ethanol in RFG3	-0.07	1.32	0.00	1.25	0.98
CNG for Medium-Duty Vehicles	0.00	0.00	0.00	0.00	0.01
CNG for Heavy-Duty Vehicles	0.00	0.01	0.01	0.01	0.08
LNG for HDVs	0.00	0.01	0.01	0.01	0.08
Fischer-Tropsch Diesel (33% Blend)	0.00	-0.12	0.00	-0.12	1.03
Biodiesel (2% Blend)	-0.01	0.10	0.00	0.09	0.10
Biodiesel (20% Blend)	-0.10	0.72	0.00	0.62	0.69

Table 4-7 Components of DENB and ECPD for the Group 3 Options

Petroleum Reduction Option	Cumulative Benefits Air Quality 2002-2030 Billion $2001	GHG 2002-2030 Billion $2001	Water Pollution 2002-2030 Billion $2001	DENB 2002-2030 Billion $2001	ECPD 2002-2030 Billion $2001
Gasoline Tax	0.71	2.02	0.10	2.83	1.33
Pay-at-the-Pump Insurance	0.58	1.66	0.08	2.32	1.09
Pay-as-you-Drive Insurance	0.55	1.24	0.06	1.85	0.81
Vehicle Miles Traveled Tax	0.58	1.32	0.06	1.96	0.86
State Feebate	0.01	1.54	0.08	1.63	1.01
Nationwide Feebate	-0.12	4.31	0.21	4.40	2.83
Registration Fee Transfer	0.11	0.33	0.02	0.46	0.22
Incentives for Efficient Vehicles	0.01	0.17	0.01	0.19	0.11

Group 2 (Fuel Substitution Options)

The Group 2 options with the highest DENB are battery electric vehicles, 10 percent ethanol blend, and grid connected hybrids. With few exceptions, all the Group 2 options yielded positive DENB and ECPD. The key findings are:

- In contrast to the Group 1 options, fuel substitution options can produce air quality benefits through both fuel cycle and reduced vehicle emissions. For this reason, in many cases the air quality benefits are roughly the same magnitude as the GHG benefits.

- Some options (LPG, E85, and biodiesel) have negative air quality benefits due to increased fuel distribution emissions.

- All options provide positive GHG benefits except the FTD blend option. This option requires use of more total energy in its fuel cycle, leading to a negative greenhouse gas effect.

- All options provide water pollution benefits except for the ethanol and methanol fuel cell options. These are negative due to the use of more volume of liquid fuels in the fuel distribution system. This is caused by the lower energy content of this fuel compared to gasoline.

- Water pollution benefits are generally an order of magnitude less than the air quality or greenhouse gas emissions.

Group 3 (Pricing Options)

Most of the Group 3 options show relatively large DENB. However, these options are very controversial in spite of their attractive DENB. These options were not included in further analyses.

5. Integration of Results

In this section, the overall Direct Net Benefit is determined by combining the DNNB with the DENB and the impact on the ECPD. Also presented is an assessment of the impact on California's economy of implementing a combination of petroleum reduction options.

5.1 Overall Costs and Benefits Results

The costs and benefits results from Sections 3 and 4 are combined to produce an overall direct net benefit result, DNB. The final DNB value for each of the options is the sum of the DNNB, DENB, and ECPD.

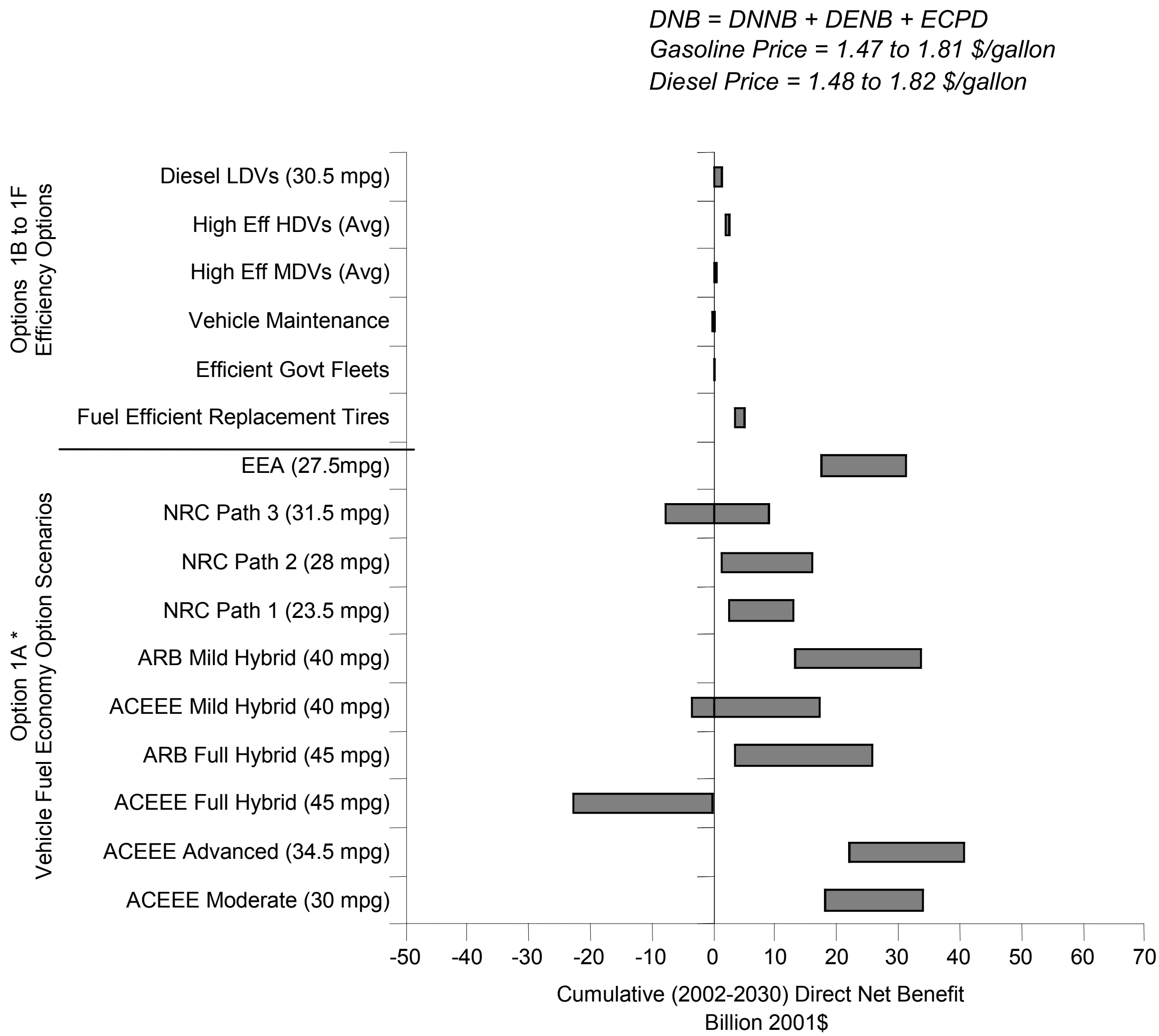
Because the Group 1 and Group 3 market penetration assumptions are so different from Group 2, direct comparison of petroleum displacement and net benefits between the Groups is not appropriate. One of the key assumptions made in this analysis is the market penetration rate. For the improved vehicle fuel economy scenarios in Group 1, 100 percent of new vehicle sales would employ the improved efficiency technologies by 2014. The 100 percent penetration was linearly phased-in over 7 years starting in 2008. Penetration rates for other Group 1 options vary. This contrasts with the Group 2 fuel substitution options, which in most cases were ramped up over 7 years to a 10 percent new vehicle market penetration rate.

In most cases, the Group 1 options result in positive direct net benefits (DNB) over the range of fuel prices considered. Figure 5-1 illustrates the cumulative 2002-2030 DNB over this range. The ACEEE Advanced fuel economy scenario provides the highest DNB, followed by the ACEEE Moderate, EEA and ARB Mild Hybrid vehicle cases. Note that the ARB mild and full hybrid cases assume lower technology costs than the ACEEE cases.

The Group 2 results are depicted in Figure 5-2. Among Group 2, the leading fuel substitution options are grid-connected hybrids and FTD. The 20-mile ZEV range hybrid, the Low Cost FFV fuel and FTD all have a positive DNB over the entire range of fuel prices. The other Group 2 options generally have negative DNB for most of the range of fuel prices considered. As discussed in Section 3, sufficiently higher gasoline prices or lower alternative fuel vehicle and fuel costs would be required before most of the alternative fuels could become economically competitive for personal vehicles.

The Group 3 integrated results are depicted in Table 5-1. The Group 3 options were only evaluated at the mid-point fuel price and it was not possible to construct bar charts for these options.

Figures 5-3 to 5-5 provide the relative values of the DNB components for the Groups 1, 2 and 3 options for the $1.64 per gallon fuel price case. All Group 1, 2 and 3 options had positive ECPD. Most Group 1 and 2 options had positive DENB.



* Fuel Economy Scenarios are based upon 100% market penetration by 2014; others vary.

Figure 5-1. Overall DNB for the Group 1 Fuel Efficiency Options and Scenarios

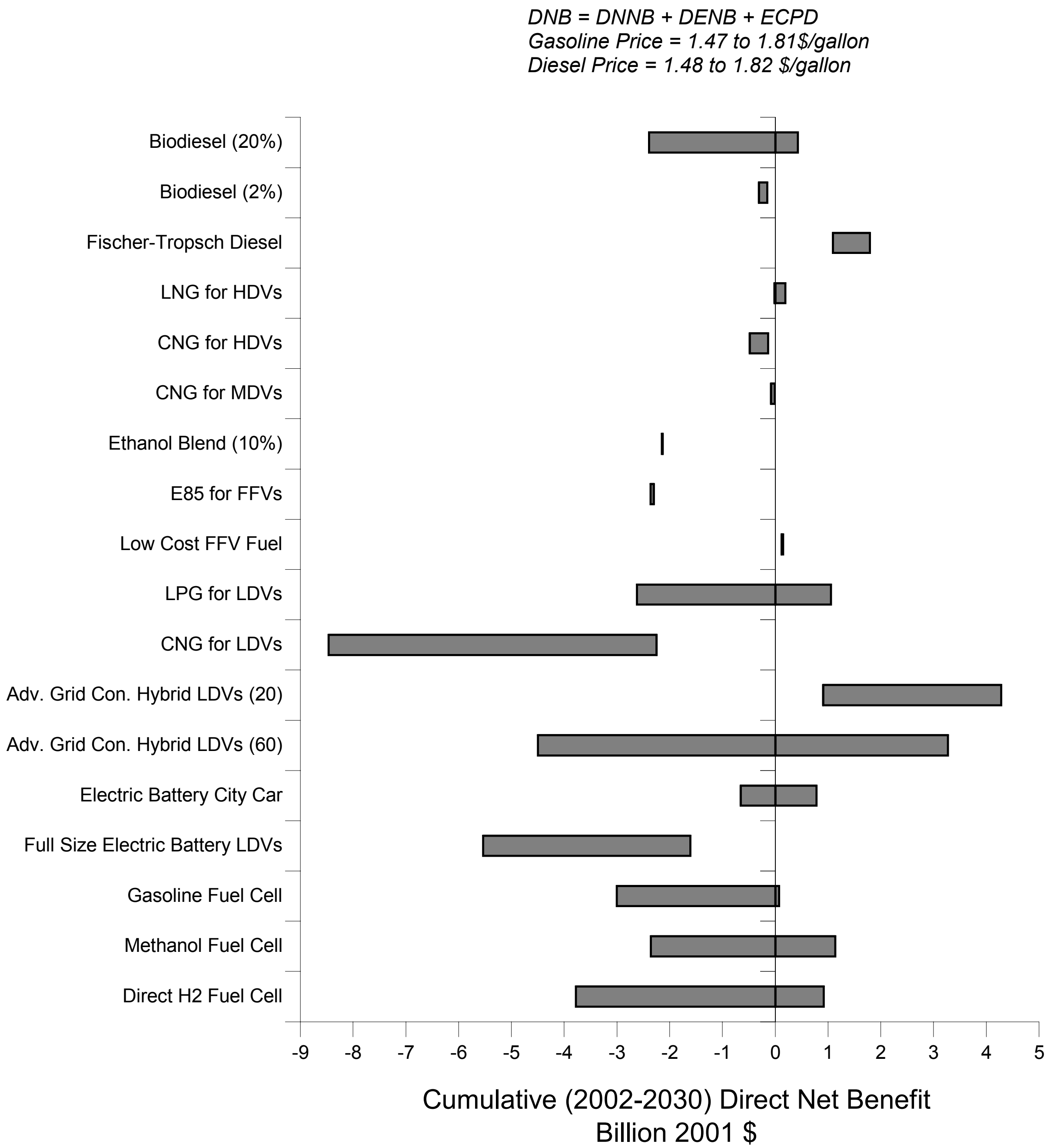


Figure 5-2. Overall DNB for the Group 2 Fuel Substitution Options

Table 5-1 Overall DNB for the Group 3 Pricing Options, Cumulative (2002-2030) Direct Net Benefit, Billion 2001 $

Option	DNNB	DENB	ECPD	DNB
Gasoline Tax ($0.50)	-5.15	2.83	1.33	-1.00
Pay-at-the-Pump Insurance	-1.23	2.32	1.09	2.18
Pay-as-you-Drive Insurance	-0.42	1.85	0.81	2.24
Tax on Vehicle Miles	-3.38	1.96	0.86	-0.56
California Feebate	6.08	1.63	1.01	8.72
Nationwide Feebate	26.9	4.40	2.83	34.13
Registration Fee Transfer	-0.46	0.46	0.22	0.22
Efficient Vehicle Incentives	-1.14	0.19	0.13	-0.84

DNNB = Direct Nonenvironmental Net Benefit
DENB = Direct Environmental Net Benefit
ECPD = External Cost of Petroleum Dependence
DNB = Direct Net Benefit

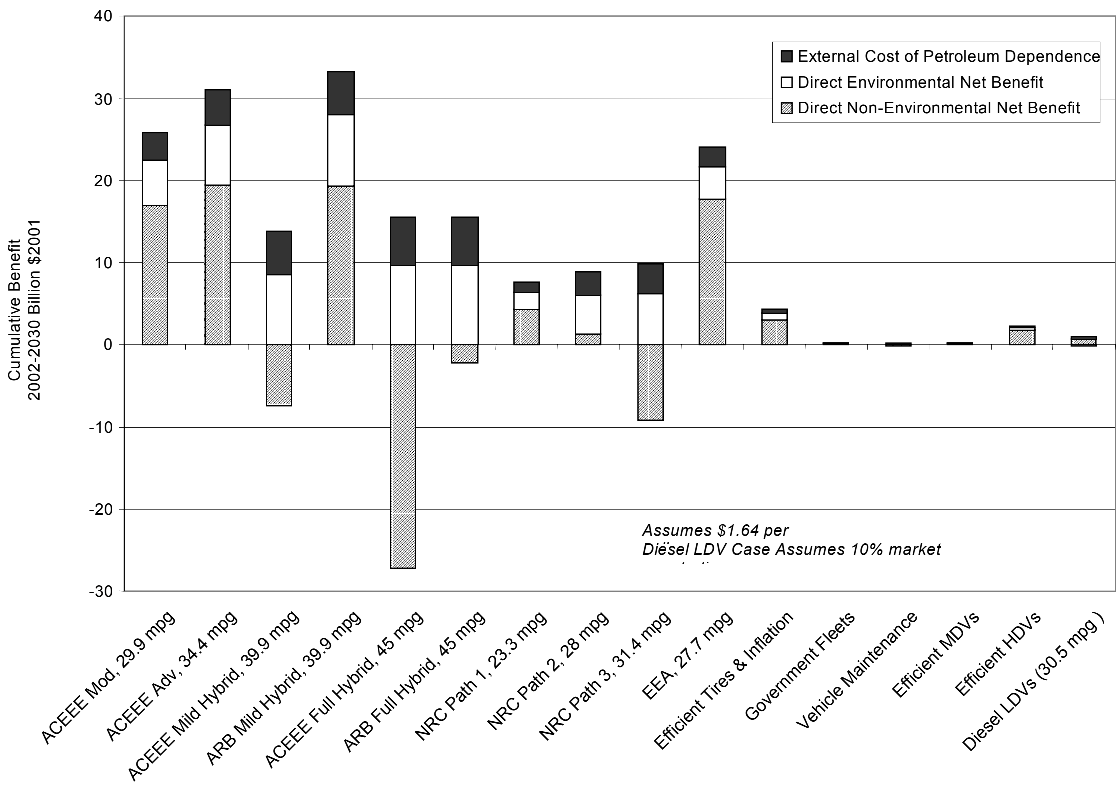


Figure 5-3. Relative Values of DNB Components for the Group 1 Options and Scenarios

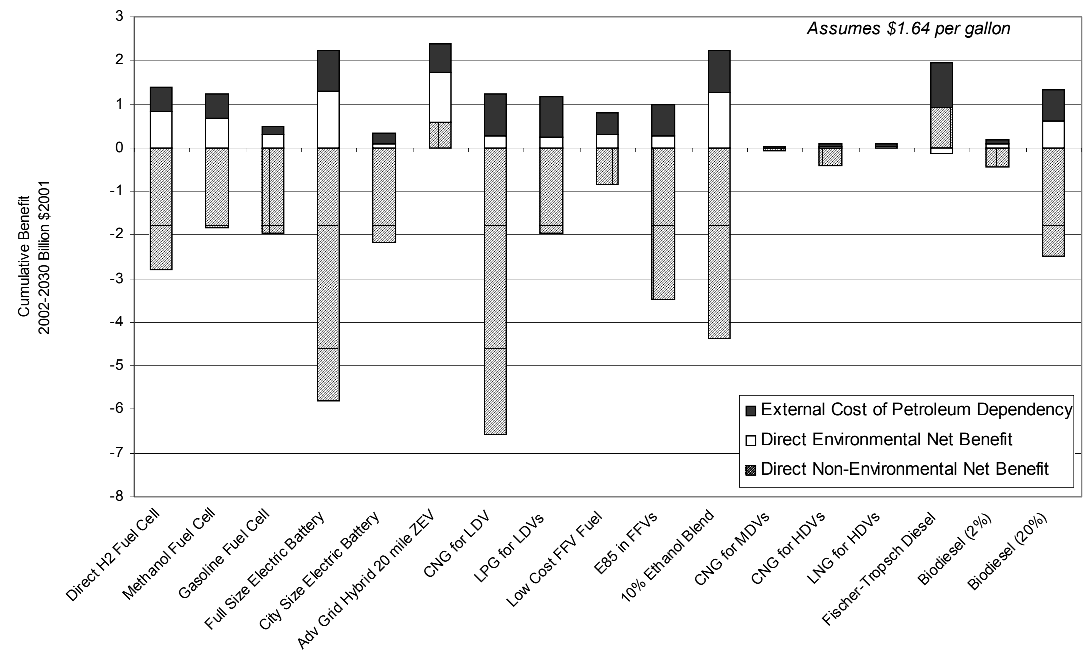


Figure 5-4. Relative Values of DNB Components for the Group 2 Options

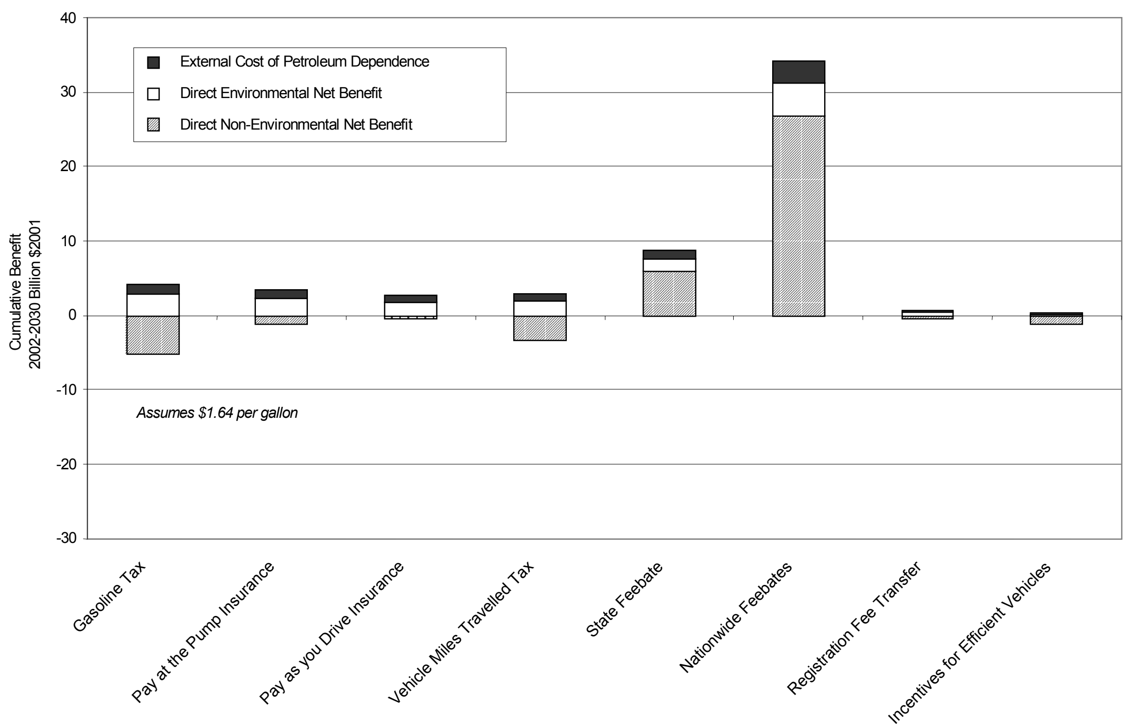


Figure 5-5. Relative Values of DNB Components for the Group 3 Options

Figures 5-6 through 5-9 show results as a function of petroleum displacement for Groups 1, 2 and 3. Only the $1.64 per gallon gasoline ($1.65 per gallon diesel) results are shown. For each figure, the symbol identifies the option or option/scenario and is plotted at the DNB result. The lower, horizontal line at the bottom of the vertical line represents the direct non-environmental net benefit results. Thus, the length of the vertical line represents the range of results, with and without the environmental benefits.

For the Group 1 options, the ARB hybrid and the ACEEE advanced fuel economy cases provide the most petroleum displacement with positive DNB. The ACEEE mild hybrid case has positive economic benefits only if the environmental and petroleum dependency benefits are included. The other fuel economy scenarios have moderate petroleum displacement results with positive DNB. The near-term Group 1 options (tires, government fleets and maintenance) yield small but meaningful petroleum displacement with positive DNB.

The light-duty diesel option is shown on the Group 1 fuel efficiency plot, but is not directly comparable to the other Group 1 options because only a 10 percent market penetration was assumed. With 10 percent market penetration, the displacement is 0.44 billion gallons of gasoline equivalent per year by 2030.

Of the light-duty Group 2 options shown in Figure 5-7, only the advanced grid-connected hybrid with 20-mile ZEV range has positive DNB. The next best light-duty cases are the low cost FFV fuel, fuel cells and LPG. These options yield large petroleum displacements with only moderately negative DNB. The full size electric battery vehicles and CNG vehicles had the most negative DNBs of all the Group 2 options.

As shown in Figure 5-8, the only heavy-duty Group 2 option with positive DNB and DNNB is the FTD blend. FTD also results in a significant reduction in petroleum consumption. This is due to the assumption that all diesel fuel would be replaced by a 33 percent FTD blend. Most of the other substitution options assumed only a 10 percent market penetration.

Of the Group 3 options, the nationwide feebate and state feebate show positive results for both DNB and DNNB. Many of the other Group 3 options show positive DNB but negative DNNB.

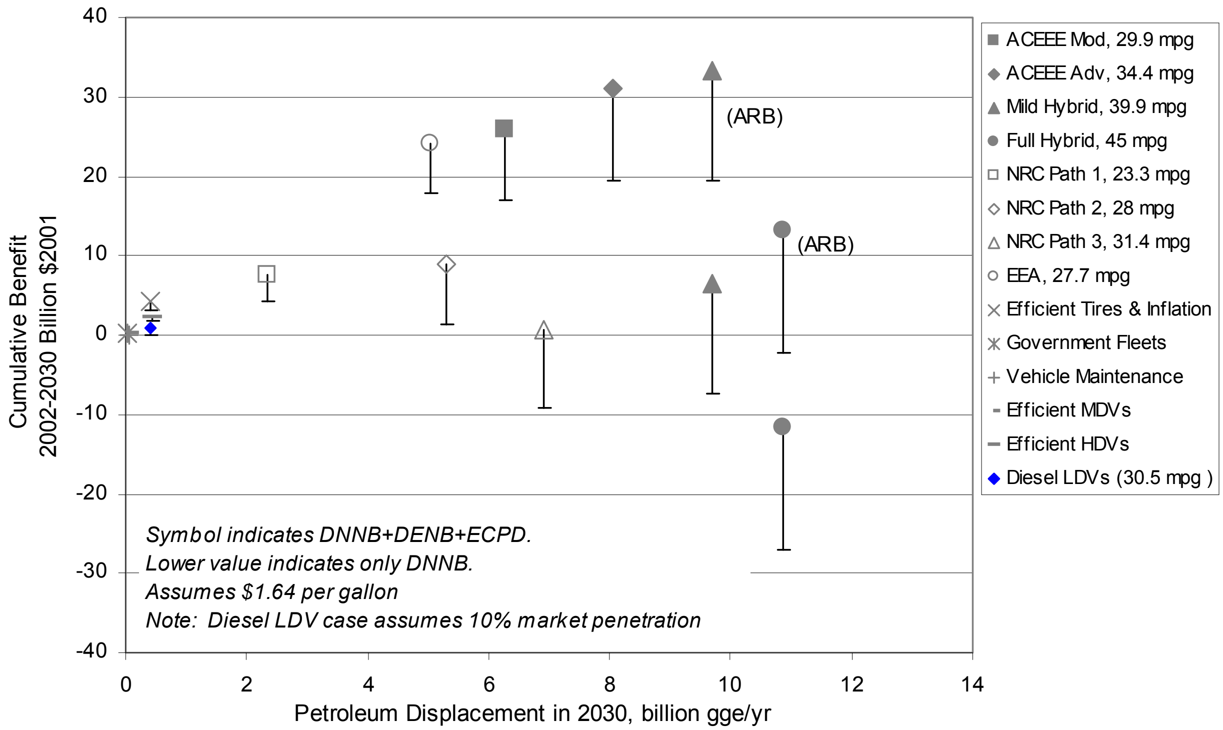


Figure 5-6. Cumulative DNB as a Function of Petroleum Displacement for the Group 1 Options and Scenarios

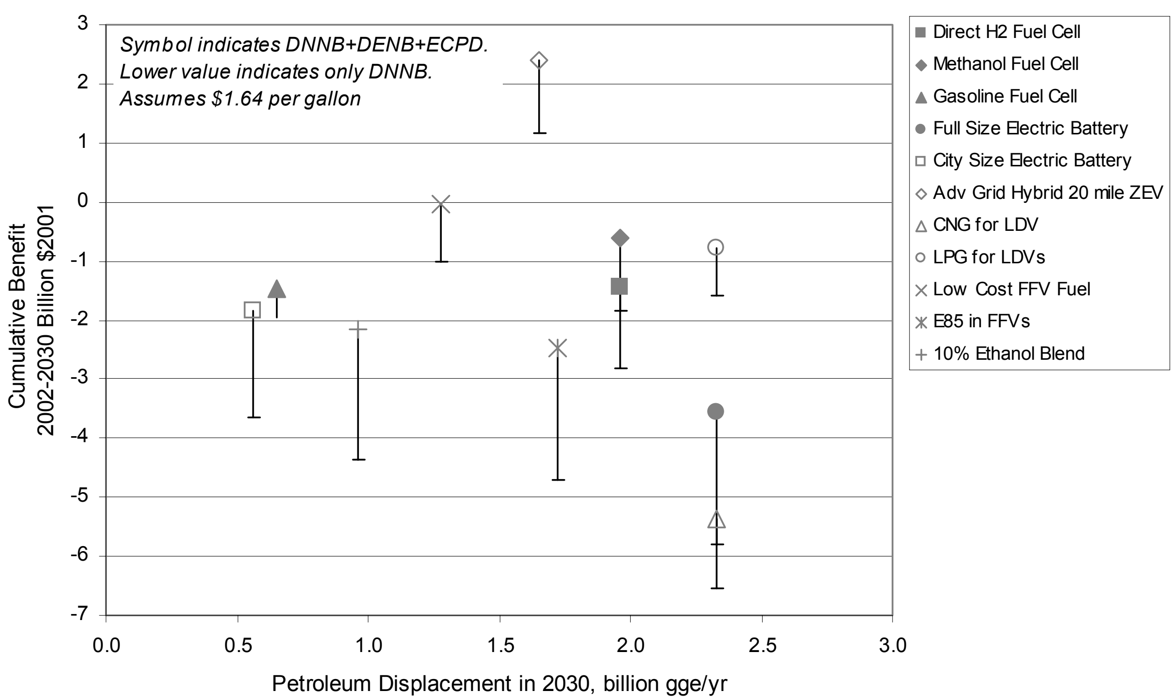


Figure 5-7. Cumulative DNB as a Function of Petroleum Displacement for the Light-Duty Group 2 Options

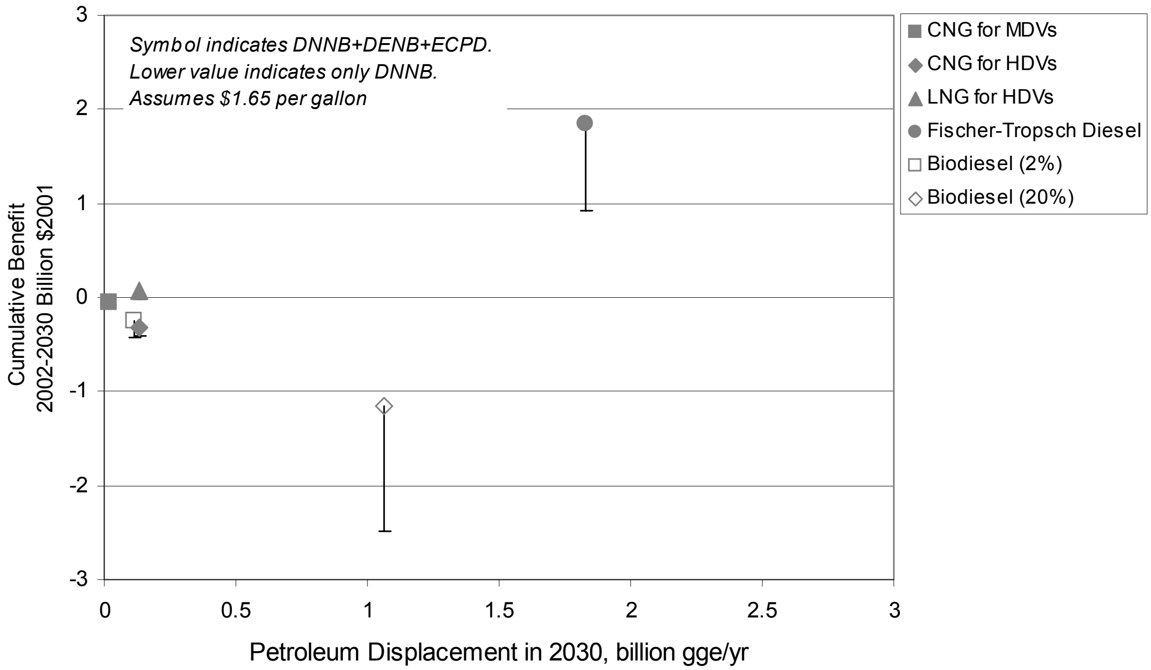


Figure 5-8. Cumulative DNB as a Function of Petroleum Displacement for the Medium- and Heavy-Duty Group 2 Options

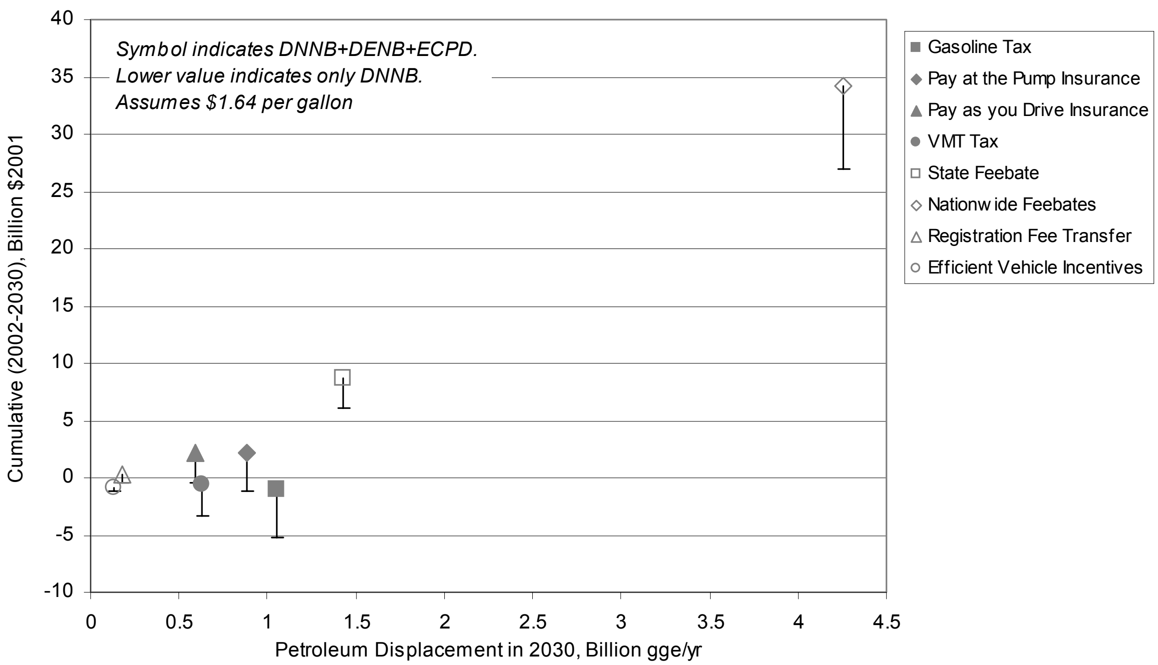


Figure 5-9. Cumulative DNB as a Function of Petroleum Displacement for the Group 3 Options

5.2 Key Findings of the Task 4 Analysis

Table 5-2 presents the petroleum displacement as well as the various components of DNNB and DENB. When all the direct costs as well as the external cost of petroleum dependency are considered, it is clear that there are many viable options for significantly reducing California's petroleum fuel use. However, to accrue these benefits, actions must be taken in the near-term.

Group 1 (Fuel Efficiency Options)

The fuel efficiency options were found to have the highest net benefits with large reductions in petroleum consumption compared to current technologies at nominal gasoline and diesel prices of $1.64 per gallon.

- The use of engine and vehicle technologies to improve vehicle fuel economy provides the largest reduction in petroleum consumption of all the options considered. Moreover, all but one of these options resulted in positive DNB. The estimated reductions in petroleum use range from 0.02 to 10.9 billion gallons per year of gasoline equivalent.

- Phasing in 40 mpg light-duty vehicles over 7 years starting in 2008 saves nearly 10 billion gallons of gasoline per year by 2030 and reduces the societal impacts of petroleum use by $6 to $33 billion cumulative to 2030.

- Use of fuel-efficient tires and proper tire inflation, the purchase of commercially available efficient vehicles by government fleets and improved vehicle maintenance practices are attractive near-term options. Although the petroleum displacement is relatively small (0.5 billion gge per year), DNB is positive ($4.6 billion cumulative to 2030). Moreover, implementation sets a positive leadership example.

- More efficient medium and heavy-duty vehicles provide a positive DNB (up to $3 billion cumulative to 2030), but result in only minor reductions in petroleum consumption (0.5 billion gge in 2030). This is mainly because most of these vehicles have diesel engines that are already relatively efficient.

- The light-duty diesel option yields a 45 percent improvement in vehicle fuel economy. This corresponds to a 0.44 billion gge reduction in petroleum use assuming a 10 percent market penetration.

Group 2 (Fuel Substitution Options)

Alternative fuels have the potential to achieve significant reductions in petroleum consumption, provided economies of scale are achieved and a convenient and cost effective fueling infrastructure is established. However, with few exceptions, the broad use of alternative fuels was found to yield negative DNB even with substantial environmental and external dependency benefits. Nevertheless, it is recognized that alternative fuels will eventually enter the transportation fuel marketplace as oil and refined product prices rise due to increasing world demand and/or depleted world oil supplies. It may be prudent public policy, therefore, to

Table 5-2. Breakdown of Direct Net Benefit

Option	Petroleum Displacement in 2030 Billion gal/yr gasoline equiv	Consumer Benefit 2002-2030 Billion $2001	Government Benefit 2002-2030 Billion $2001	**DNNB** 2002-2030 Billion $2001	Air Quality Benefit 2002-2030 Billion $2001	Greenhouse Gas Benefit 2002-2030 Billion $2001	Water Quality Benefit 2002-2030 Billion $2001	**DENB** 2002-2030 Billion $2001	**ECPD** 2002-2030 Billion $2001	**DNB** 2002-2030 Billion $2001
1 Fuel Efficiency Improvements										
ACEEE Moderate, 29.9 mpg	6.28	26.74	-9.81	16.92	0.24	5.10	0.25	5.59	3.35	25.86
ACEEE Advanced, 34.4	8.04	32.10	-12.56	19.54	0.30	6.54	0.32	7.16	4.30	31.00
ACEEE Mild Hybrid, 39.9	9.71	7.89	-15.17	-7.28	0.36	7.90	0.39	8.65	5.19	6.56
ARB Mild Hybrid, 39.9	9.71	34.59	-15.17	19.42	0.36	7.90	0.39	8.65	5.19	33.26
ACEEE Full Hybrid, 45	10.86	-10.18	-16.96	-27.15	0.41	8.83	0.44	9.68	5.80	-11.67
ARB Full Hybrid, 45	10.86	14.74	-16.96	-2.23	0.41	8.83	0.44	9.68	5.80	13.25
NRC Path 1, 20.5	2.34	7.93	-3.65	4.28	0.09	1.90	0.09	2.08	1.25	7.61
NRC Path 2, 21	5.30	9.57	-8.29	1.29	0.20	4.31	0.21	4.73	2.84	8.85
NRC Path 3, 31.4	6.90	1.68	-10.79	-9.10	0.26	5.62	0.28	6.15	3.69	0.74
EEA, 26.7	5.03	24.75	-6.97	17.78	0.17	3.63	0.18	3.97	2.38	24.14
Fuel Efficient Tires & Inflation	0.41	4.54	-1.50	3.04	0.03	0.71	0.03	0.78	0.47	4.28
Government Fleets	0.02	0.21	-0.04	0.17	0.00	0.02	0.00	0.02	0.01	0.21
Vehicle Maintenance	0.05	0.18	-0.31	-0.14	0.00	0.10	0.00	0.10	0.06	0.03
MDV Mild Improvement	0.05	0.18	-0.08	0.10	0.00	0.04	0.00	0.04	0.02	0.17
MDV Aggressive Improvement	0.09	0.39	-0.14	0.25	0.00	0.07	0.00	0.07	0.04	0.36
Efficient MDVs	0.07	0.29	-0.11	0.18	0.00	0.05	0.00	0.06	0.03	0.26
HDV Mild Improvement	0.27	1.53	-0.42	1.10	0.01	0.20	0.01	0.21	0.11	1.43
HDV Aggressive Improvement	0.58	3.25	-0.90	2.35	0.01	0.42	0.02	0.45	0.24	3.05
Efficient HDVs	0.43	2.39	-0.66	1.73	0.01	0.31	0.01	0.33	0.18	2.24
Light Duty Diesel (30.5 mpg)	0.40	1.03	-0.35	0.68	-0.42	0.33	0.02	-0.07	0.29	0.90
2 Fuel Substitution										
Direct H2 fuel Cell	1.96	-1.20	-1.60	-2.80	0.33	0.46	0.04	0.83	0.55	-1.43
Methanol Fuel Cell	1.96	-1.24	-0.59	-1.84	0.34	0.35	-0.01	0.68	0.55	-0.61
Gasoline Fuel Cell	0.65	-1.42	-0.53	-1.96	0.01	0.28	0.01	0.31	0.18	-1.47
Full Size Electric Battery	2.33	-3.40	-2.40	-5.80	0.41	0.81	0.07	1.29	0.94	-3.57
City Size Electric Battery	0.56	-1.57	-0.60	-2.17	0.04	0.04	0.02	0.10	0.23	-1.84
Advanced Grid Hybrid 20 mile ZEV	1.65	2.43	-1.85	0.58	0.17	0.92	0.05	1.14	0.67	2.39
CNG for LDV	2.33	-5.05	-1.54	-6.59	0.06	0.16	0.07	0.29	0.94	-5.36
LPG for LDVs	2.33	-1.93	-0.03	-1.96	-0.09	0.25	0.07	0.24	0.94	-0.78
Low Cost FFV Fuel	1.28	-0.04	-0.81	-0.84	-0.05	0.37	-0.01	0.31	0.50	-0.03
E85 in FFVs	1.72	-0.13	-3.34	-3.47	-0.08	0.39	-0.02	0.28	0.70	-2.48
10% ethanol blend	0.96	0.00	-4.38	-4.38	-0.07	1.32	0.00	1.25	0.98	-2.15
CNG for MDVs	0.02	-0.03	-0.03	-0.06	0.00	0.00	0.00	0.00	0.01	-0.05
CNG for HDVs	0.13	-0.25	-0.17	-0.41	0.00	0.01	0.01	0.01	0.08	-0.32
LNG for HDVs	0.13	0.13	-0.15	-0.01	0.00	0.01	0.01	0.01	0.08	0.07
Fischer-Tropsch Diesel (33%)	1.83	0.93	0.00	0.93	0.00	-0.12	0.00	-0.12	1.03	1.84
Biodiesel (2%)	0.11	-0.43	0.00	-0.43	-0.01	0.10	0.00	0.09	0.10	-0.25
Biodiesel (20%)	1.06	-2.76	0.29	-2.48	-0.10	0.72	0.00	0.62	0.69	-1.16
3 Pricing Options										
Gasoline Tax	1.05	-98.48	93.32	-5.15	0.71	2.02	0.10	2.83	1.33	-1.00
Pay at the Pump Insurance	0.88	1.35	-2.58	-1.23	0.58	1.66	0.08	2.32	1.09	2.18
Pay as you Drive Insurance	0.59	1.35	-1.77	-0.43	0.55	1.24	0.06	1.85	0.81	2.23
Vehicle Miles Travelled Tax	0.63	-84.30	80.92	-3.38	0.58	1.32	0.06	1.96	0.86	-0.56
State Feebate	1.43	8.57	-2.49	6.08	0.01	1.54	0.08	1.63	1.01	8.72
Nationwide Feebates	4.26	34.15	-7.25	26.90	-0.12	4.31	0.21	4.40	2.83	34.13
Registration Fee Transfer	0.17	0.05	-0.51	-0.46	0.11	0.33	0.02	0.46	0.22	0.22
Incentives for Efficient Vehicles	0.13	16.96	-18.10	-1.14	0.01	0.17	0.01	0.19	0.11	-0.84

DNNB =Direct Nonenvironmental Net Benefit, DENB = Direct Environmental Net Benefit, ECPD = External Cost of Petroleum Dependence, DNB = Direct Net Benefit continue to share the risks with industry to develop and deploy alternative fueled vehicles and infrastructure.

- Phasing in the blending of synthetic diesel fuel (FTD) for all heavy-duty diesel vehicles over 12 years starting in 2008 yielded moderate reductions in petroleum consumption (1.8 billion gge in 2030) with positive DNB ($1.6 billion cumulative to 2030).

- Development of the advanced grid-connected hybrid electric vehicles with 20-mile ZEV range could also result in moderate reductions in petroleum consumption with a positive DNB.

- LNG for heavy-duty diesels had a slightly positive DNB, but yields only a small reduction in petroleum consumption (0.13 billion gge in 2030).

- LPG for light duty vehicles resulted in the largest reduction in petroleum consumption of all the Group 2 options (2.3 billion gge in 2030 with 10% market penetration). However, DNB was slightly negative (-$0.8 billion cumulative to 2030), due to higher consumer costs compared to conventional light-duty vehicles.

- The direct hydrogen fuel cell light-duty vehicle may be the best long-term option with DNB only slightly more negative than the LPG case (-$1.4 billion cumulative to 2030). This option can displace approximately 2 billion gge per year with a 10 percent market share. While the direct hydrogen fuel cell vehicle petroleum displacement is not quite as large as in the LPG option, the GHG emissions are 50 percent lower.

Group 3 (Pricing Options)

Several of the pricing options provide significant petroleum reductions and positive DNB. The national feebate case has the largest DNB of all options studied. However, as stated elsewhere, the pricing options are very controversial and were excluded from the final steps of the analysis.

5.3 Possible California Economic Impacts of Petroleum Reduction Strategies

An additional question explored related to the economic impact of combinations of options or strategies that substantially reduced the amount of gasoline and diesel fuel used in the state. This was explored using a sophisticated, general equilibrium economic model of California. This model has been used for evaluating tax proposals and environmental regulations with large fiscal impacts on the California economy. The model solves for the market-clearing prices of goods and services and factors of production.

The model is structured to describe 102 distinct sectors including industrial, consumer retail, labor and capital, household, investment, government, and the rest of the world. Petroleum is included in refining, crude production, imported crude and refined products, intermediate goods purchased by transportation and other sectors, consumer purchases, and direct tax revenues. The model does not evaluate short-term phenomena such as temporary gasoline supply disruptions. Equilibrium in the context of this model generally takes 3 to 5 years.

Three modeling years were analyzed: 1998/99 baseline year, 2020, and 2050. The model was calibrated for 1999 data and then baseline modeling was completed for 2020 and 2050 using projected population and state personal income and an estimate of petroleum industry output in those years. This analysis, unlike the life cycle costing methodology previously discussed, calculates costs and benefits of various strategies in 2020 and 2050. Nevertheless, the results provide a check to see if various strategies would have a negative impact on the California economy.

Table 5-3 shows the assumptions used in the modeling. These assumptions are consistent with the baseline modeling described in Section 2. The Energy Commission's forecast methodology uses California Department of Finance data for state personal income and population and then predicts petroleum demand. Consumption and production values were estimated using the forecasted prices for crude and refined products. For this analysis, California refining capacity was allowed to grow from 1999 levels until 2020 at 0.5 percent per year and California crude production was reduced from 2.73 million barrels per year in 1999 to 0.90 million barrels per year in 2020 and no production in 2050. Similarly, Alaskan production was reduced from 3.87 million barrels per year in 1999 to 0.19 million barrels per year in 2020 and no production in 2050. Imports make up the shortfalls in crude oil and refined products.

Table 5-3. Modeling Assumptions for California Economy

	1998/99	2020	2050
State Personal Income (billions of 2001$)	$892	$2,007	$4,319
Population (millions)	34.7	45.5	68.2
Petroleum Consumption (billions of 2001$)	$28.6	$56.6	$98.9
Production (billions of 2001$)	$32.4	$52.4	$52.5
Net Refined Imports (billion of 2001$)	$-3.8	$4.1	$46.4

Four strategies were analyzed in 2020 and 2050. Each of the strategies included blending FTD with conventional diesel fuel combined with various light-duty fuel economy strategies. The light-duty options that were combined with FTD (or Gas to Liquids, GTL) are summarized as follows:

1. EEA, fuel efficiency options phased in over time ultimately providing a light-duty on road fuel economy of 27.7 mpg.

2. ACEEE advanced fuel efficiency options phased in over time and providing a light-duty on road fuel economy of 34.4 mpg.

3. ACEEE moderate fuel economy option phased in over time coupled with fuel cell vehicles phased in starting in 2020 to level off gasoline and diesel demand to 2000 levels.

4. ACEEE full hybrid fuel economy option phased in over time and providing a light-duty on road fuel economy of 45 mpg.

These strategies were selected to provide the range of costs and benefits shown in Table 5-4. The most aggressive strategy, which includes full hybrids, has costs that exceed benefits in 2020 and 2050. All other strategies have benefits that exceed costs. Most of the costs and most of the benefits were allocated to private consumers with the remaining costs and benefits going to industry. The added costs of technology went to the engine manufacturing sector and all industrial sectors require more of this sector to produce a unit of output.

Table 5-4. Modeling Input Strategies

Strategy	2020 (million 2001$)		2050 (million of 2001$)	
	Costs	Benefits	Costs	Benefits
1. EEA LDV +GTL Blend	2,187	3,264	5,858	14,614
2. ACEEE Advanced+GTL Diesel Blend	4,824	9,284	7,752	19,746
3. ACEEE Moderate+GTL Blend+Fuel Cell Vehicles	7,970	8,269	20,782	26,170
4. ACEEE Full Hybrid+GTL Blend	13,660	12,533	22,054	29,896

The results of the analyses for 2020 are summarized in Table 5-5 for the four strategies considered. Similar results were obtained for 2050 and can be found in the Task 1 report.

The conclusion of this analysis is that none of the strategies considered had much of an effect on the California economy. Even the most aggressive strategy did not substantially reduce state output. All strategies resulted in lower effective fuel prices and the savings associated with these lower prices are spent on items like apparel and food. Consumers, whose income is largely wages, see an increase in their real incomes. Not unexpectedly, the petroleum sector does not expand as much given petroleum reduction strategies and the model tends to favor importing more refined product rather than using California based production. Petroleum production also declines and both of these factors lead to a slight reduction in state output. Non-wage payments to consumers are reduced and consumers with a high fraction of income from capital see their real incomes decreased in most of the strategies.

Table 5-5. Impact on California Economy of Petroleum Reduction Strategies

2020	BASE MODEL	Strategy 1	Strategy 2	Strategy 3	Strategy 4
CA OUTPUT ($BILLION)	3078.0223	3074.9243	3070.0183	3069.4120	3062.4866
% CHANGE CA OUTPUT	0.10%	-0.10%	-0.26%	-0.28%	-0.50%
CA PERSONAL INCOME ($BILLION)	2009.5373	2009.5213	2010.4295	2006.5412	2001.0251
% CHANGE CA PERS. INC.	0.11%	0.00%	0.04%	-0.15%	-0.42%
LABOR DEMAND (MILLIONS)	18.6605	18.6767	18.7119	18.6841	18.6726
% CHNGE LABOR DEMAND	0.03%	0.09%	0.28%	0.13%	0.06%
PRICE OF CFOOD	1.0001	1.0001	1.0002	1.0013	1.0026
PRICE OF CHOME	1.0000	1.0000	1.0001	1.0008	1.0018
PRICE OF CFUEL	1.0000	0.9687	0.9111	0.9215	0.8818
PRICE OF CFURN	1.0001	1.0001	1.0002	1.0011	1.0022
PRICE OF CCLOTH	1.0001	1.0001	1.0002	1.0011	1.0023
PRICE OF CTRANS	1.0000	1.0072	1.0171	1.0271	1.0513
PRICE OF CMED	1.0001	1.0002	1.0006	1.0020	1.0038
PRICE OF CAMUS	1.0000	1.0001	1.0002	1.0013	1.0027
PRICE OF COTHR	1.0000	1.0000	1.0001	1.0008	1.0017
ENMIN					
OUTPUT ($BILLION)	6.2086	6.0575	5.7836	5.7448	5.6084
% CHANGE OUTPUT	0.08%	-2.43%	-6.84%	-7.47%	-9.67%
IMPORTS ($BILLION)	36.0105	34.8290	32.6693	32.5922	31.8337
% CHANGE IMPORTS	0.07%	-3.28%	-9.28%	-9.49%	-11.60%
EXPORTS ($BILLION)	1.0965	1.1122	1.1419	1.1430	1.1542
% CHANGE EXPORTS	-0.07%	1.43%	4.15%	4.25%	5.27%
PETRO					
OUTPUT ($BILLION)	39.3048	37.6902	34.7300	35.3868	33.5161
% CHANGE OUTPUT	0.07%	-4.11%	-11.64%	-9.97%	-14.73%
IMPORTS ($BILLION)	15.6834	15.5646	15.3455	15.3992	15.2814
% CHANGE IMPORTS	0.01%	-0.76%	-2.15%	-1.81%	-2.56%
EXPORTS ($BILLION)	11.9979	12.0739	12.2159	12.1807	12.2582
% CHANGE EXPORTS	-0.02%	0.63%	1.82%	1.52%	2.17%
ENGIN					
OUTPUT ($BILLION)	40.4675	40.5818	40.6323	40.6730	40.8046
% CHANGE OUTPUT	0.05%	0.28%	0.41%	0.51%	0.83%
IMPORTS ($BILLION)	9.0494	9.0815	9.1111	9.1578	9.2482
% CHANGE IMPORTS	0.02%	0.35%	0.68%	1.20%	2.20%
EXPORTS ($BILLION)	13.8359	13.7822	13.7330	13.6559	13.5091
% CHANGE EXPORTS	-0.03%	-0.39%	-0.74%	-1.30%	-2.36%
CHEMS					
OUTPUT ($BILLION)	30.2836	30.6482	31.3101	32.0653	31.6679
% CHANGE OUTPUT	0.22%	1.20%	3.39%	5.88%	4.57%
IMPORTS ($BILLION)	39.3028	39.2943	39.2798	39.3585	39.4178
% CHANGE IMPORTS	0.01%	-0.02%	-0.06%	0.14%	0.29%
EXPORTS ($BILLION)	2.0905	2.0910	2.0918	2.0872	2.0838
% CHANGE EXPORTS	-0.01%	0.02%	0.06%	-0.16%	-0.32%
FOODS					
OUTPUT ($BILLION)	92.9579	95.1127	99.2793	98.4497	101.3527
% CHANGE OUTPUT	0.14%	2.32%	6.80%	5.91%	9.03%
APPAR					
OUTPUT ($BILLION)	25.9513	26.4969	27.6314	27.1334	27.5086
% CHANGE OUTPUT	0.20%	2.10%	6.47%	4.55%	6.00%
MOTOR					
OUTPUT ($BILLION)	18.2243	18.1613	18.0770	18.0142	17.8553
% CHANGE OUTPUT	0.23%	-0.35%	-0.81%	-1.15%	-2.02%